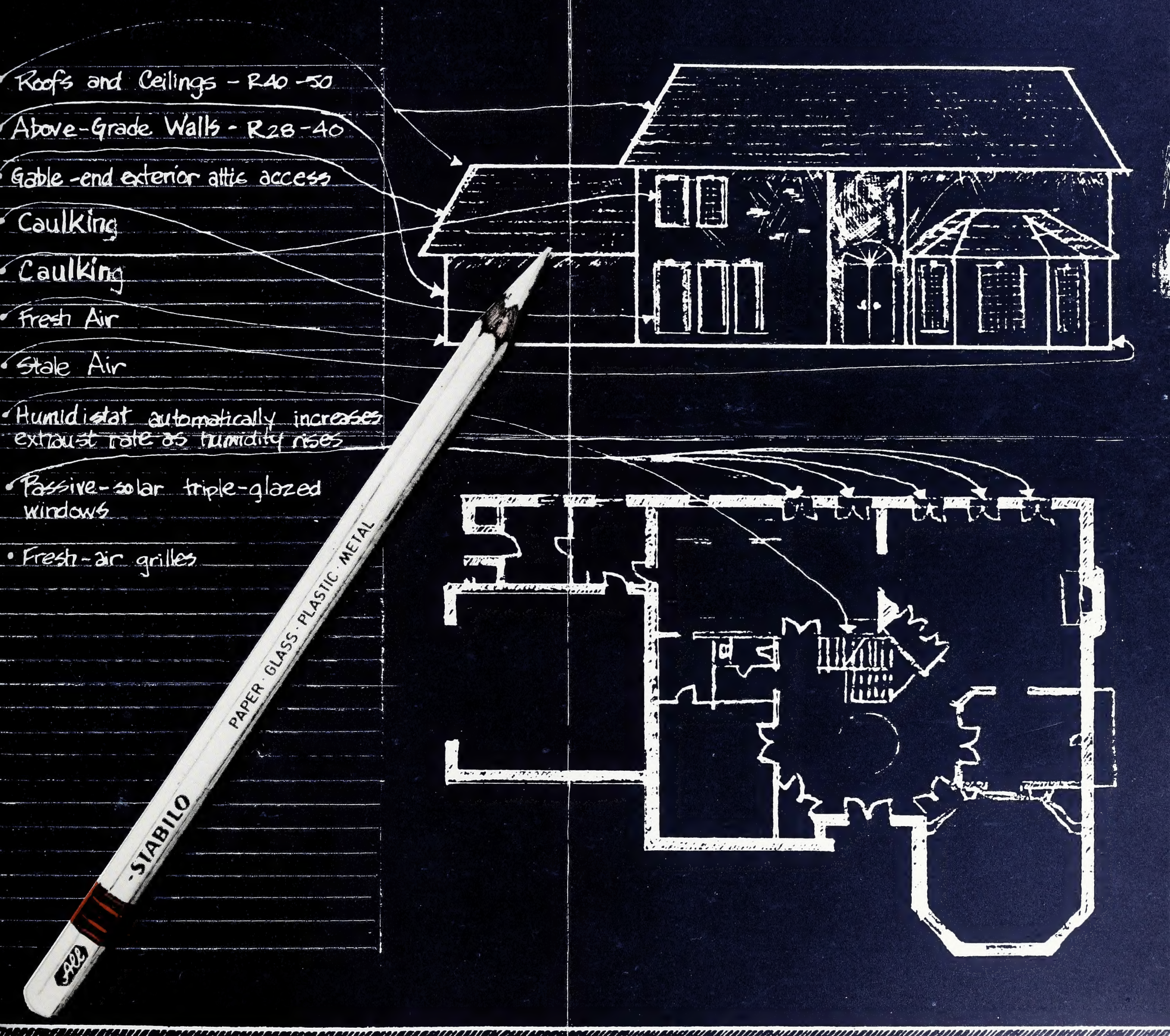
A GUIDE TO ENERGY-EFFICIENT HOUSING



- UPGRADE CEILINGS TO R-50
- INSTALL HUMIDISTAT
- SEAL VAPOR BARRIER
- ADD CONIFEROUS TREES TO NORTH FACADE

ENERGY EFFICIENT HOUSING

SCALE - 1" : 23"

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A GUIDE TO ENERGY-EFFICIENT HOUSING

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Alberta Educational
Communications Corporation

ENERGY-EFFICIENT HOUSING is a twelve-program series of videotapes, which deals with both new homes and older homes requiring retrofitting. The explanations and illustrations of the many facets of low-energy housing in this *Guide* supplement the information in the videotapes. The first six programs concentrate on the energy-efficient planning, construction, and operation of new homes. The last six programs apply the same principles and techniques to the retrofitting of existing homes.

The *Guide* was written and illustrated by Blaine Marler.

Each videotape has a running time of 28:30 minutes. The program order numbers and titles are:

BPN
2353 01 NEW HOMES: The Energy-Efficient House
2353 02 NEW HOMES: Starting Efficiently
2353 03 NEW HOMES: Making It Cozy
2353 04 NEW HOMES: The Airtight House
2353 05 NEW HOMES: Heating Choices
2353 06 NEW HOMES: Letting The Sun Shine In
2353 07 EXISTING HOMES: Keeping The Heat In
2353 08 EXISTING HOMES: Plugging The Holes
2353 09 EXISTING HOMES: Basements and Attics
2353 10 EXISTING HOMES: Walls and Windows
2353 11 EXISTING HOMES: Heating Alternatives
2353 12 EXISTING HOMES: Energy-Efficient Lifestyles

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NEW HOMES: THE ENERGY-EFFICIENT HOUSE

OUTLINE

This initial program in the *Energy-Efficient Housing* series is an overview of what will be explained and illustrated in more detail in later programs. Their material deals with both new and renovated housing, showing methods to apply during construction and operation that will lower home energy requirements. Topics that will be covered include principles of heat loss, economics of fuel use, aspects of construction, types of heating systems, and owners' lifestyles. The information presented in this introductory program emphasizes the simplicity, advantages, and long-term benefits of energy-efficient housing.

A. Energy-Efficient Housing

1. What Is It?

An energy-efficient home can be defined as one that uses anything from one-quarter to one-third of the amount of energy required to operate a similarly sized, conventionally constructed home. Energy is required for space heating, domestic hot water heating, appliance operation, ventilation, and for lighting. The greatest energy requirement is for space heating—up to 70% in most standard homes—so an energy-efficient house is one in which that demand has been drastically reduced.

Table 1-1 HOME ENERGY REQUIREMENTS

	Hot Water(%)	Elec.(%)	Space Heat(%)	Total
Standard home	40 GJ* (18)	30 GJ (13)	155 GJ (69)	225 GJ
Energy-efficient home	20 GJ (36)	20 GJ (36)	15 GJ (28)	55 GJ

*gigajoules

Table 1-1 shows standard-home energy consumption versus energy-efficient requirements. The units of energy used are in gigajoules—a metric unit—but the actual unit used to measure the fuel is irrelevant. (Table 1-2 gives metric to Imperial conversions that are used in the programs.) Note, however, that the total fuel use for the energy-efficient home is *only 24% that of the standard home.* And note, too, that the largest saving is in the area of space heating.

Table 1-2 TYPICAL METRIC CONVERSION FACTORS

1 W (watt) = 3.412 btu/hr.	1 mm (millimetre) = 0.039 in.
1 GJ = 948,000 btu	1 m (metre) = 3.28 ft.
1 RSI = 5.71 R	1 m^2 = 10.76 $ft.^2$
	1 m^3 = 35.3 $ft.^3$
1 L (litre) = 0.22 gal.	1 kg (kilogram) = 2.205 lb.

2. What Should It Cost?

The construction of an energy-efficient house should only cost from 5% to 8% more than a conventionally constructed house. This means that the average house should cost $3000 to $5000 (in '84 dollars) extra to be constructed in an energy-efficient manner. As a result, it should realize at least $700 yearly in energy savings. This means that the **simple payback** on that extra investment would be:

$$\frac{\text{Total investment — \$5000}}{\text{Yearly savings — \$700}} = 7.1 \text{ years}$$

Simple payback assumes that the rate of interest approximates the inflation rate in the price of fuel. If fuel prices rise slowly, the payback period will be longer; if they rise swiftly, the period will be shorter. A seven-year payback is quite a good investment.

The same economic justification holds true for remodelling situations. Older homes with no improvements made to them in terms of energy efficiency will be consuming $3000 to $4000 per year of energy in the not-too-distance future. Remodelling for energy conservation—often referred to as **retrofitting**—can reduce energy bills by at least two-thirds. Investing $5000 now in retrofitting may result in a very short payback period, depending on fuel prices and type. For example, low-cost fuels such as natural gas mean longer payback periods than do such higher-priced fuels as electricity.

3. What About Solar Energy?

An energy-efficient house is the result of lowering the energy requirements through high insulation levels and sealing the building envelope against air leakage. In addition, the efficient use of appliances, lights, ventilation, and the heating system aid in lowering demands. With such low requirements, conventional fuel sources that everyone is familiar with—oil, natural gas or electricity—can easily *and cheaply* supply the small amounts required. And because the demands are so small, expensive alternatives like active solar-energy systems are not, currently, economically viable for single-family residences.

Active solar-energy systems involve the use of collectors, pumps, fans, and storage components to operate. They require energy to collect, move,

store, retrieve, and distribute heat. Because of the very high equipment investment and ongoing maintenance involved, active solar-energy systems cannot economically compete with the simpler approach of building a home with low energy demands. However, as later programs will illustrate, properly oriented energy-efficient homes can take advantage of **passive solar energy** (sunlight coming in through windows).

Passive solar-energy systems require no extra energy to operate. They are usually an intrinsic part of the home design. South-facing windows and thermal mass are considered at the design stage and become an integral part of the home as it is built. As a result, passive systems have little cost, operate as long as the sun shines, and need little or no maintenance.

4. Is Economics The Only Reason?

Going beyond economics, there are many other reasons besides saving energy for constructing an energy-efficient home or retrofitting an existing one. These benefits can include lower interior noise levels, higher comfort levels, increased winter humidity levels, fewer draughts, and a higher potential resale value.

B. Home Heat Losses

There are two major ways in which the typical house loses heat. One, which accounts for up to 40% of the total loss, is referred to as **air-leakage** heat loss. The other, which makes up the remaining 60%, is called **transmission** heat loss.

1. Air-Leakage Heat Losses

This type of heat loss occurs where air can leak in or out of the building "envelope" (the exterior shell of the structure). Since hot air rises, it is constantly trying to leak out of any cracks, joints, or holes near the top of a house (Figure 1-1). It is impossible to create a vacuum, so this leaking hot air is replaced by cold, outside air, which leaks in through cracks, joints, or holes in the lower part of the house.

The cold air that leaks in is heated to room temperature, which causes it to rise and try to leak out. This phenomenon is known as the **stack effect**.

Air-leakage heat losses can also be increased by the wind. Increased pressure on the exterior windward side forces in cold air through any cracks or holes. Decreased pressure on the leeward side draws hot air out (Figure 1-2).

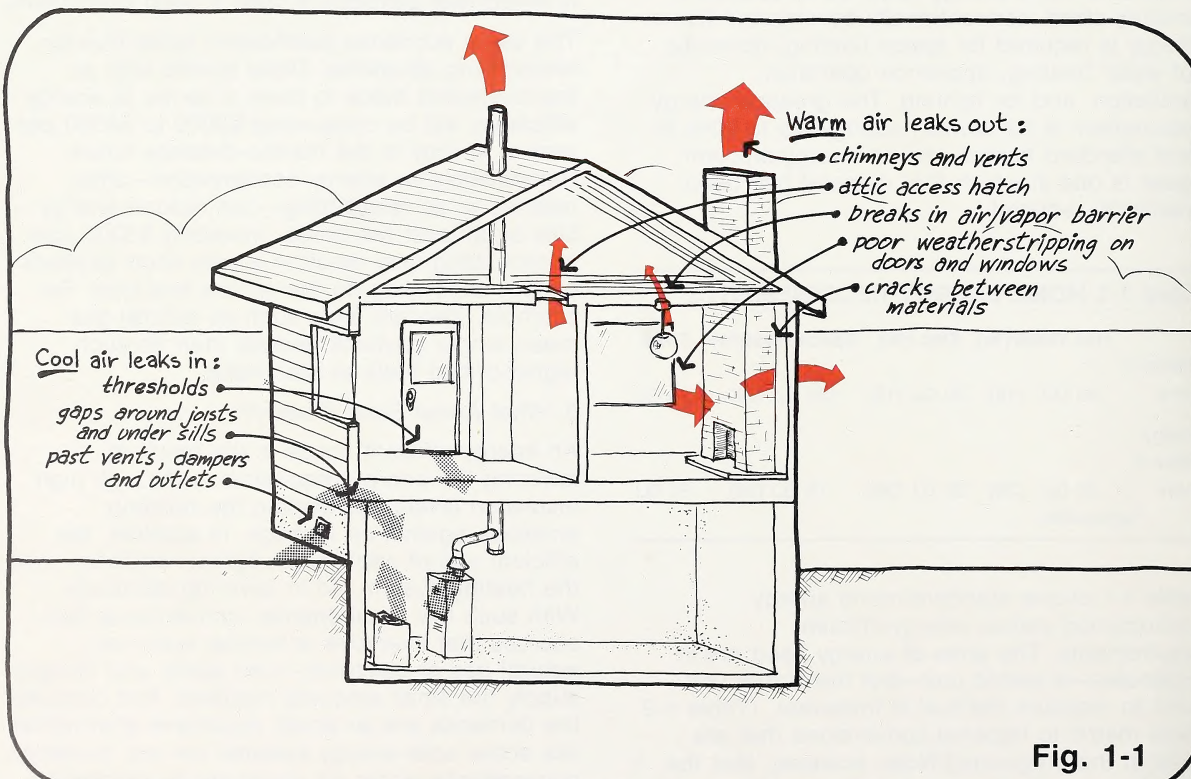


Fig. 1-1

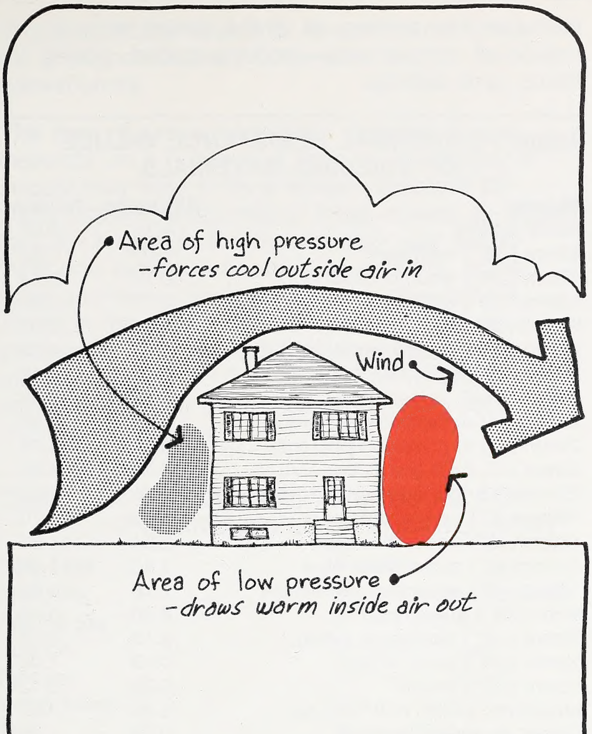


Fig. 1-2

Air-leakage heat losses are often termed **infiltration**, because you can often feel the cold air coming in, or "infiltrating." There is usually very little pressure difference between inside and outside. So, for every bit of cold air infiltration there is an equal amount of warm air "exfiltration"—*air you've paid to heat!*

Sources of air leakage in a home can easily be detected. By holding a smouldering piece of cotton string, a cigarette, or a commercially available smoke pencil near suspected areas of leakage, paths of incoming air can be identified. (Checking for air leakage should be done on a cool and windy day with all the exhaust fans in the home turned on to create as much "vacuum" as possible.) Potential sources of air leakage include the framework around windows and doors, electrical outlets, baseboards, milk chutes, weatherstripped areas—in general, any place where two different materials or surfaces meet. Mark any places where air leakage is detected for caulking, weatherstripping, or gasket installation.

2. Transmission Heat Losses

Transmission heat losses occur when heat moves by conduction, radiation, and/or convection through the materials that make up

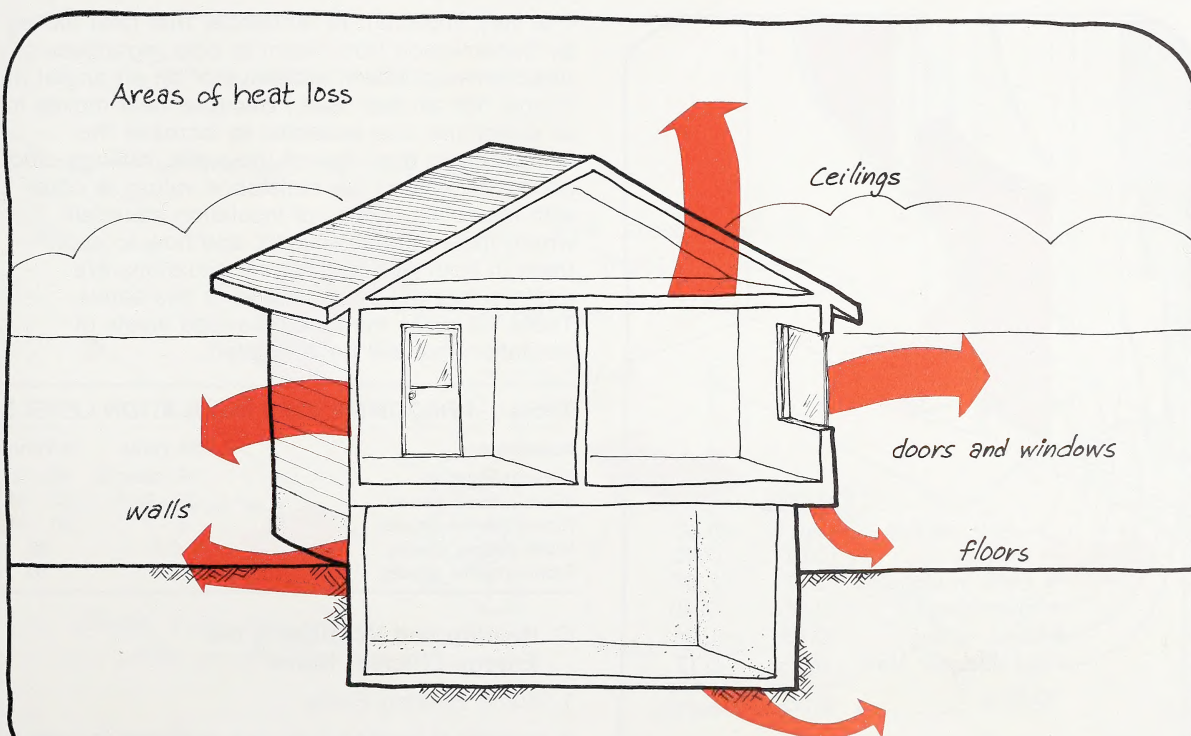


Fig. 1-3

the walls, floors, ceilings, doors, and windows of a house (Figure 1-3). The rate of heat flow through any material, or combination of materials, depends on the **resistance** to heat flow and on the **temperature** (t°) **difference** from one side of the material to the other. Resistance to heat flow is often referred to as the R-value in Imperial terms or the RSI-value in metric: the higher the R- or RSI-value, the better the thermal resistance to heat flow.

Thermal resistance values are given for a number of different building materials in Table 1-3. The total resistance value for any building surface is the sum total of the values of each layer (Figure 1-4). To calculate the rate of heat loss through any surface, the following equation is used:

$$\text{Heat loss} = \frac{\text{surface area} \times t^\circ \text{ difference}}{\text{thermal resistance value}}$$

Heat loss values will be in **watts** if the area is in square metres, the inside to outside temperature difference is in °C, and the thermal resistance is in RSI-values. The heat loss will be in **British Thermal Units** (btu) if the area is in square feet, the temperature difference in °F, and the thermal-resistance value in R-values. The total transmission heat loss from a house can be calculated by adding up all the losses from individual components—walls, windows, doors, floors, and ceilings.

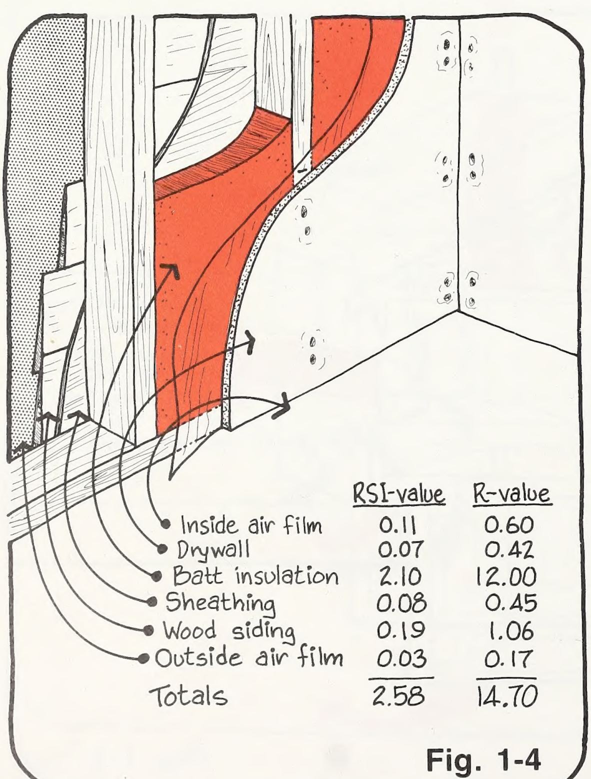


Fig. 1-4

Table 1-3 THERMAL RESISTANCE VALUES OF BUILDING MATERIALS

Material	RSI-Value	R-Value
Inside air film	0.11	0.60
12mm (1/2") wallboard	0.07	0.42
19mm (3/4") wood boards	0.17	0.94
12mm (1/2") air space	0.17	0.94
Window glass	0.006	0.03
90mm (3 1/2") solid wood	0.77	4.38
200mm (8") concrete	0.26	1.49
90mm (3 1/2") glass fibre	2.10	12.00
25mm (1") expanded polystyrene	0.69	3.96
25mm (1") extruded polystyrene	0.87	4.96
25mm (1") rigid glass fibre	0.74	4.25
25mm (1") rigid urethane/isocyanurate	1.31	7.50
150mm (6") cellulose fibre	3.80	21.70
150mm (6") wood shavings	2.54	14.50
150mm (6") blown glass fibre	2.43	13.90
150mm (6") expanded vermiculite	2.16	12.35
9mm (3/8") sheathing	0.08	0.45
12mm (1/2") hardboard siding	0.13	0.73
19mm (3/4") wood siding	0.19	1.06
15mm (5/8") stucco	0.02	0.12
Metal/vinyl siding with backing	0.25	1.41
Carpet (synthetic backing)	0.23	1.29
Hardwood flooring	0.12	0.69
Outside air film	0.03	0.17

It is very important to remember that heat moves by transmission from warm to cold *regardless of direction*—up, down, sideways or on an angle! (It is only hot air that rises.) Because heat moves in all directions, it is essential to increase the resistance to heat flow of the walls, ceilings, *and floors*. Increasing the resistance values is done with insulation. Types of insulation materials, where they should be used, and how to apply them in both new and retrofit situations are matters that will be explained in this series. Table 1-4 gives the recommended levels of insulation that will be illustrated:

Table 1-4 RECOMMENDED INSULATION LEVELS

Assemble	RSI-Value	R-Value
Ceilings/Roofs	7 - 9	40 - 50
Walls (above grade)	5 - 7	30 - 40
Floors (above grade)	5 - 7	30 - 40
Walls (below grade)	3.5	20
Floors (below grade)	1.7	10

C. Heating and Ventilating the Energy-Efficient Home

1. Home Heating Fuels

A number of heating fuels are available for use in single-family homes. Electricity, natural gas, and fuel oil are predominant where transmission and transportation networks are commonly available.

Propane, wood, coal and, to some extent, fuel oil, are types that are obtainable less conveniently.

The type of fuel a household chooses to use depends on a number of factors. Availability of supply may vary in local areas—distance to transmission/transportation lines, mines, or wood lots, for example. Prices can also vary widely from one region to another. In addition, some fuels are more convenient to use than others. There is much more effort and maintenance involved in burning wood than natural gas, for example. Table 5-1 lists some fuel types, together with the quantities required to obtain an equal heat amount.

Table 1-5 FUEL QUANTITY REQUIRED FOR ONE GIGAJOULE OF USEABLE HEAT*

Fuel Type	Quantity
Electricity	279,000 watts (279 kwh)
Natural gas	27 m^3 (1185 $ft.^3$)
Fuel oil	34 litres (7.5 gal.)
Propane	53 litres (11.6 gal.)
Wood (birch)	97 kg (213 lb.)
Coal	83 kg (182 lb.)

*Burning fuels in appliances with typical efficiencies

2. Types of Heating Systems

There are two main methods of distributing heat in homes. Radiant heating systems provide a heat source in a space or room (Figure 1-5). The space is heated by **convection** (hot air rising) as the heat source transfers its energy to the air in the space or room. Radiant convectors are typically heated by hot water or electricity (Figure 1-6), but also include individual space heaters like wood stoves.

Forced-air heating systems use a central source for burning fuel to heat air that is distributed via a fan and ductwork to all the spaces required. This type of system has the advantage that any internal sources of heat or passive solar gain in the space are also picked up and evenly distributed about the entire building. A typical forced-air system is illustrated in Figure 1-7. Table 1-6 lists some of the efficiencies that can be attained when burning different types of fuels in different types of systems.

3. Heating System Operation

Any heating system will function most efficiently when it is sized accurately, that is, when it provides the amount of heat needed for the particular building it is heating. Oversized

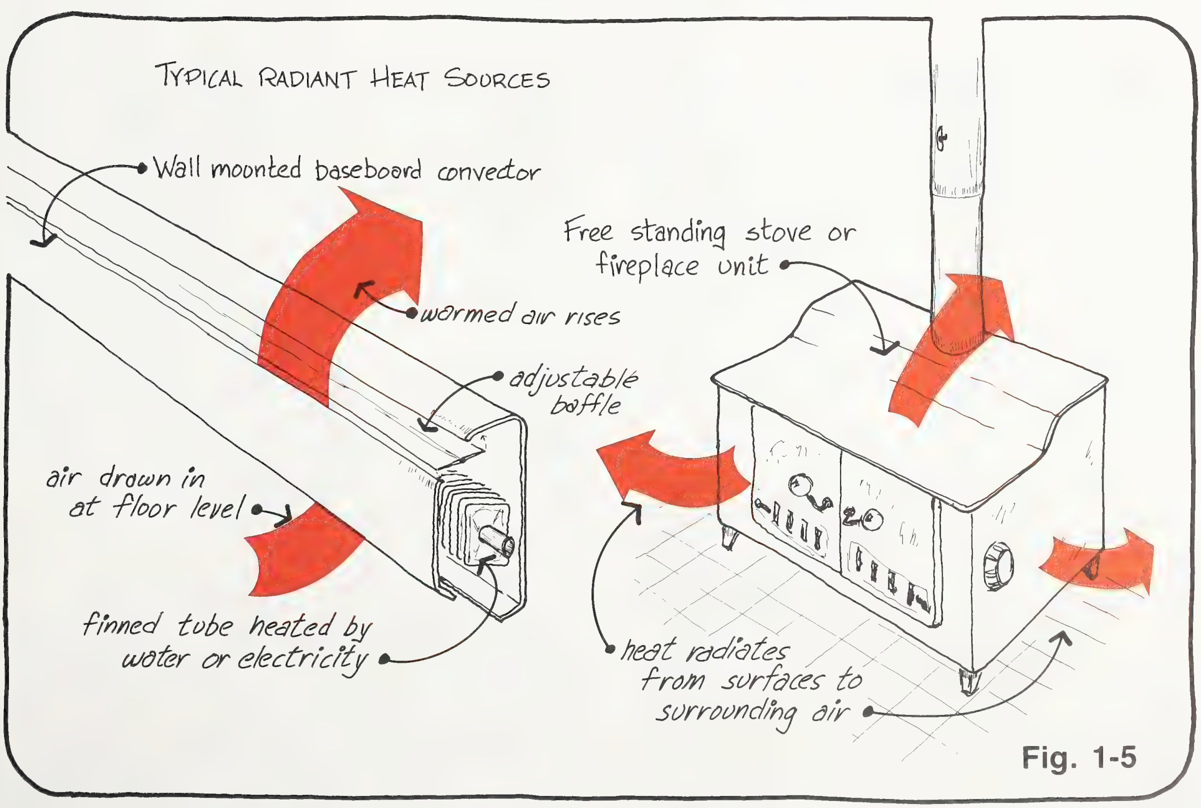


Fig. 1-5

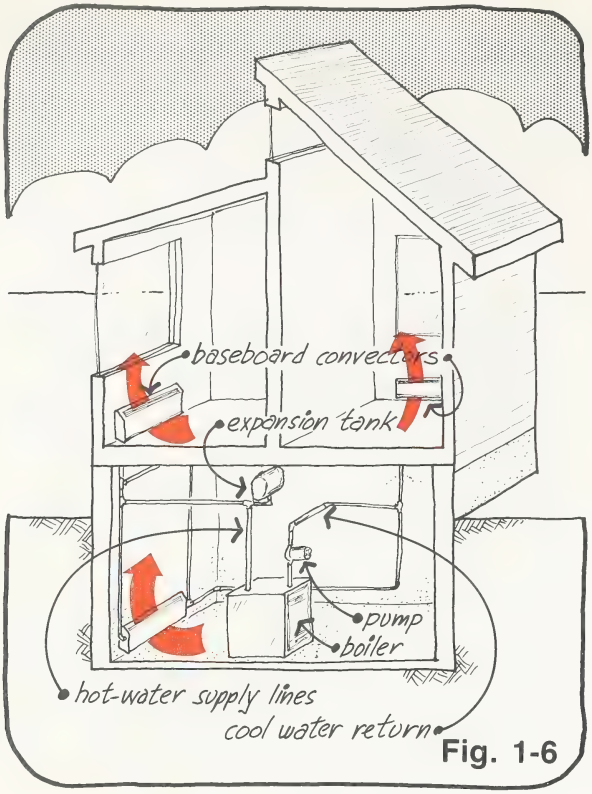


Fig. 1-6

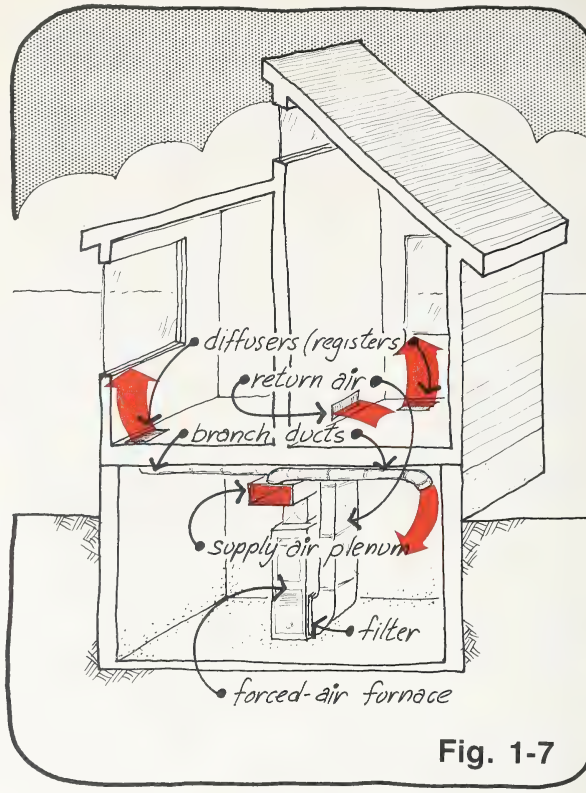


Fig. 1-7

heating equipment will tend to cycle on and off frequently, leading to inefficient fuel use and reduced equipment service life. In a furnace or boiler, for example, much energy is wasted when the appliance is started because the heat exchanger must be warmed before heat can be transferred to the air. The more times a unit must start from cold, the more inefficient it will be. An efficiently-sized system will operate for longer periods and be idle for longer periods as well. And energy-efficient structures require quite *small* heating systems because of their very *low* space heating demand.

Table 1-6 FUEL/SYSTEM EFFICIENCY

Fuel Type	System	Typical Efficiency
Electricity	All types	95 - 99%
Gas	Standard furnaces	55 - 70%
	High-efficiency furnaces	75 - 90%
	Space heaters	50 - 60%
Fuel oil	Furnaces	60 - 75%
	Space heaters	50 - 60%
Wood	Fireplaces	5 - 35%
	Furnaces	50 - 65%
	Stoves	55 - 70%
Coal	Furnaces	55 - 70%
	Stoves	50 - 65%

However, because very cold exterior temperatures may occur every few years, the heating system of a home should be designed to provide about 30% more than the **design heating load.** The design heating load for a home is calculated before it is constructed. The areas of all the exterior surfaces, plus their respective RSI-values, are used in conjunction with the expected difference between inside and outside temperatures to calculate the total heat loss on a cold winter day. The simple formula on page 4 is used by heating and ventilating contractors to calculate heat loss by transmission. Adding that to expected air-leakage heat losses (which depend on the degree of sealing) indicates the size of heating system to install.

4. Combustion Air

Any fuel-burning appliance requires air for combustion as well as for proper chimney operation. Since energy-efficient homes tend to be well sealed, *a separate inlet for combustion air is needed.* In fact, this will probably be a local building code requirement. Although improvements made to fuel-burning appliances have included electronic ignition, flue (chimney) dampers, and condensing exhaust heat exchangers, air is still required during flame operation.

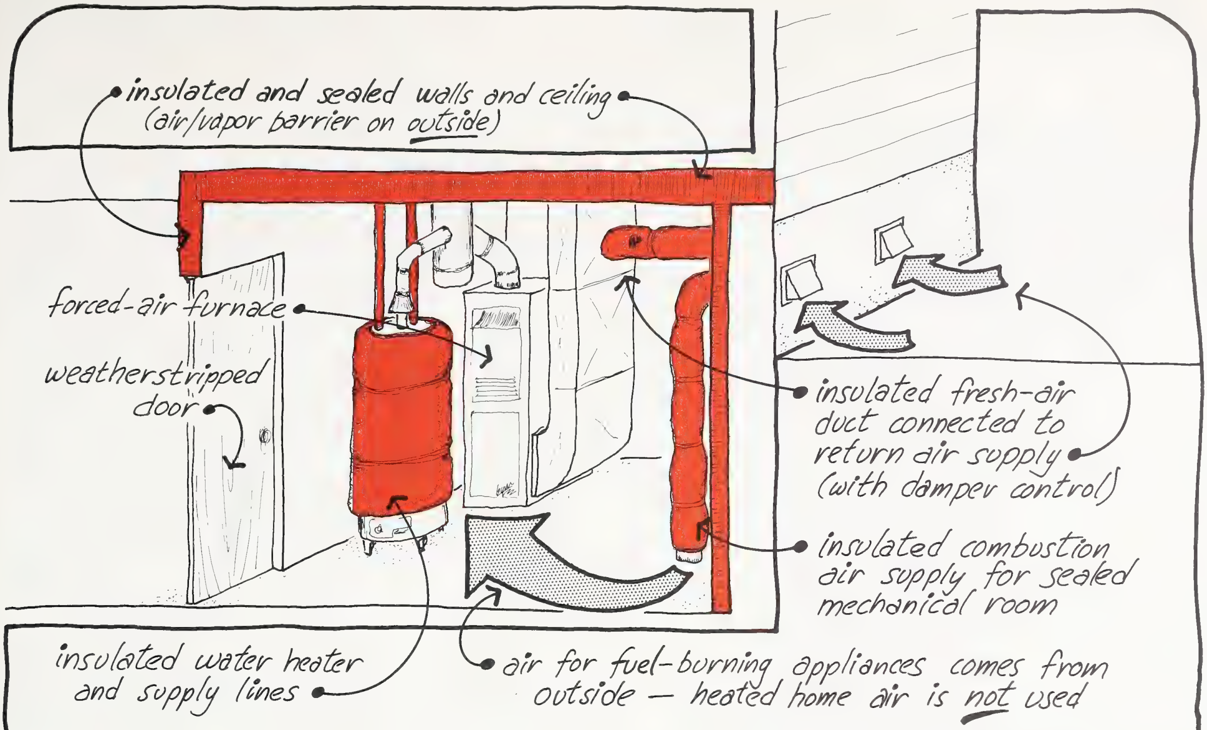


Fig. 1-8

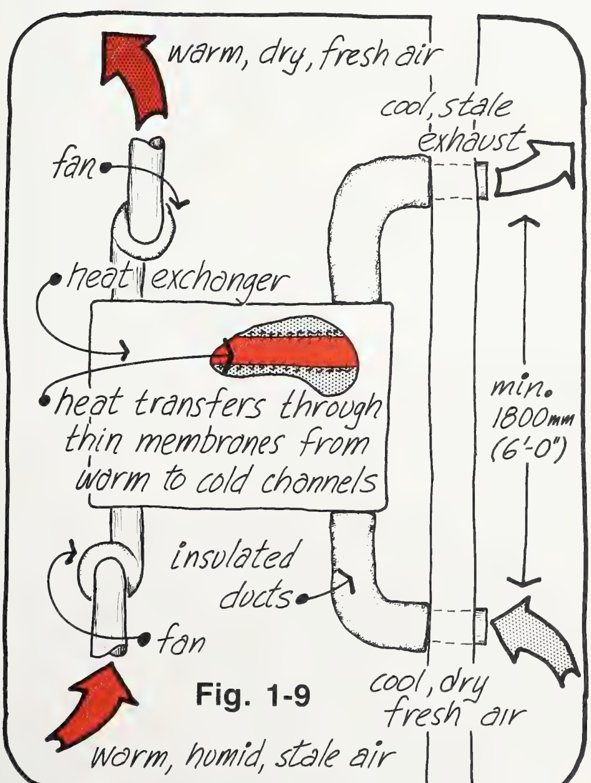


Fig. 1-9

Isolating the fuel-burning appliance in a room with its own air supply (Figure 1-8) is one way of making sure that heated air from the home is not used for combustion. Two inlets into such a space will ensure there is adequate combustion air, as well as a supply of fresh air to the structure.

5. Ventilating Systems

Fresh air for the occupants of a home is an important operational consideration. Although the object of an energy-efficient house is to make it as air-tight as possible, *the entire volume should be changed every three or four hours.* This will prevent the build-up of humidity, odors, and pollutants that will occur in a totally sealed volume.

This exchange of stale for fresh air can be accomplished with a mechanical ventilation system. Fans, in moisture- or odor-producing areas, will replace the exhausted air through an inlet vent. However, a great deal of heat is also exhausted along with the stale air.

A solution to recapturing the heat from exhausting air is an **air-to-air heat exchanger** in the ductwork (Figure 1-9). The exhausting stale air is passed by the incoming fresh air. The heat transfers from the warm air through thin membranes separating the two air flows. The exhausted air is humid but cool, while the fresh

air enters the home dry and warm. Air-to-air heat exchangers are capable of retaining up to 80% of the heat energy wasted to the outdoors.

Summary

The principles of energy-efficient housing are:
- high levels of insulation
- low rates of air leakage
- efficient heating systems
- controlled ventilation.

It is important to remember that living in and operating an energy-efficient home does *not* require a change in lifestyle for the occupants. If anything, the comfort level of an energy-efficient home is higher, and at a much reduced energy-use cost, than in conventional housing. A more even interior temperature, fewer drafts, and an increased winter humidity level are definite gains —as is a cooler environment during the summer.

Family lifestyle does, however, have an effect on energy consumption. Two families living in identical houses can find their utility bills varying by a factor of two or more depending on how they "operate" their home. Hot water usage, how often openings like doors and windows are used, thermostat settings, and lighting operation all determine energy consumption. Combining low-energy family habits with a well-constructed home will result in very low energy usage and costs.

NEW HOMES: STARTING EFFICIENTLY

OUTLINE

Air leakage (infiltration and exfiltration) *can account for at least one third* (40%) *of the total heat loss from a house.* This leakage occurs around windows and doors, through cracks between materials, around ducts, pipes, and conduits, up chimneys, out loose exhaust dampers, and past electrical fixtures.

This program details what must be done in the initial stages of design and construction when building an energy-efficient house. There are a number of considerations if you want to end up with an air-tight structure. Two major ones are that all potential air-leakage sources be identified and the house sealed during construction. Care in building has to begin at the foundation stage and be continued to final completion.

A. Air-Leakage Heat Losses

The average home has a volume of about 550 cubic metres or 19,000 cubic feet. (Table 1-2 on page 1 lists some common metric conversions.) In this home, air tends to leak out and is replaced by cool outside air at the rate of one or two house volumes of air per hour. In an energy-efficient house, this leakage rate is reduced to one-third or one-quarter of a house volume per hour. By not having to heat the excess of infiltrating air, potential savings of 15% to 20% on your annual fuel bill are quite feasible.

1. Air-Vapor Barrier

A polyethylene vapor barrier has been a standard construction component for many years. Placed on the warm side of the insulation (the interior side), it prevents moist air from entering the insulation and condensing as it cools to form water or ice (Figure 2-1). Moisture in the wall cavity will destroy the insulation value and, in addition, produce structural deterioration of wood. This vapor barrier, however, also functions as an air barrier—hence the name "air-vapor barrier."

Recent testing has shown that severe air leakage occurs past joints in the vapor barrier, around punctures for vents, stacks, and electrical fixtures, through door and window rough openings, and around partition walls at ceiling and exterior wall joints. Using a heavier thickness of polyethylene (6 mil instead of 2 mil) and sealing it at all joints can control this air leakage and resultant heat loss. A good air-vapor barrier sealant is **acoustical caulking**, or **solvent-based acrylic caulking.**

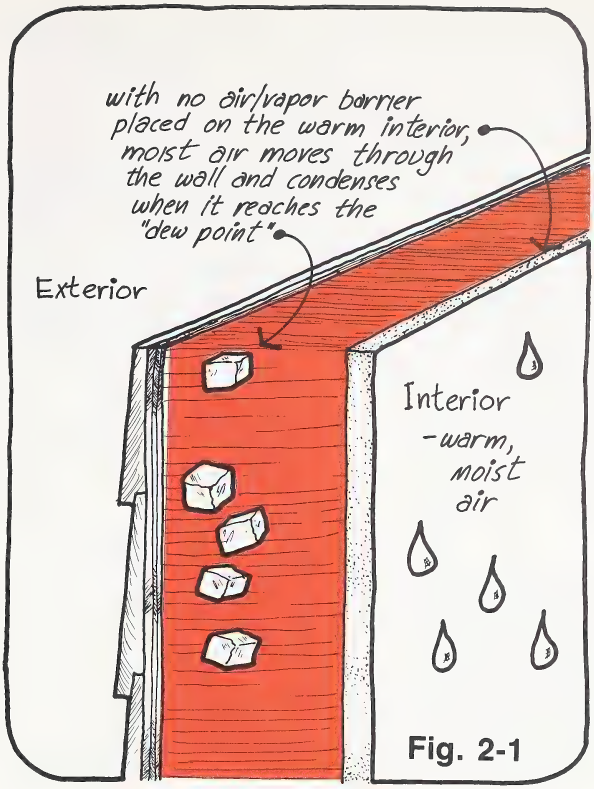


Fig. 2-1

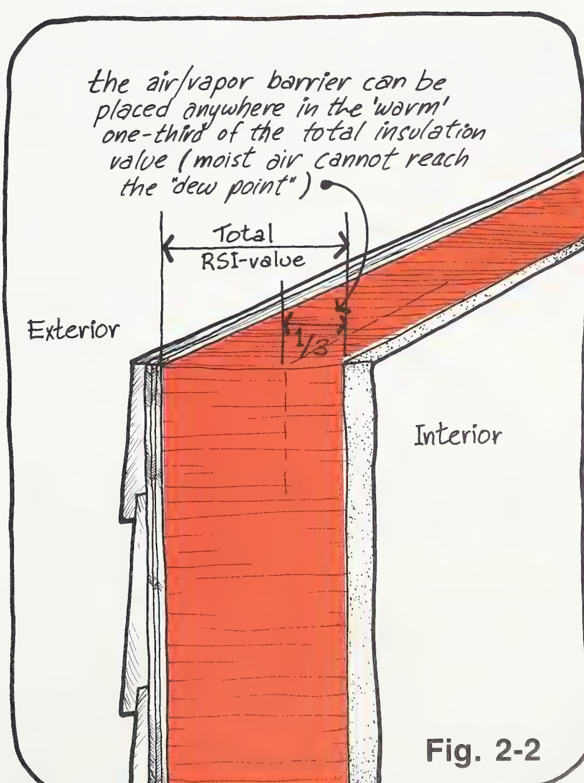


Fig. 2-2

Leaving the vapor barrier unsealed around all the potential leakage points is like leaving a 600mm square (2') window open all year round! Recent tests have also indicated that the air-vapor barrier does *not* have to be placed right on the warm side of the wall—it can be located anywhere in the first one-third of the insulation (measured from the warm side, as in Figure 2-2).

Uncontrolled air leakage through a poorly installed air-vapor barrier is caused by the stack effect and by wind pressure (both explained and illustrated earlier). These are the losses called infiltration because you can usually feel the cold air coming in or "infiltrating" the building envelope. Since there is very little pressure difference between inside and outside, there is an equal amount of exfiltration.

2. Condensation

There are many sources of moisture in the home. People (and pets) release moisture through breathing and bathing or showering. Cooking and clothes washing can all contribute to the humidity. As much as 10kg (22 lb.) of water may be added to the atmosphere in an average house every day. High rates of air leakage in older homes easily remove this excess humidity. As a matter of fact, most homes in dry winter climates have to have humidifiers to add moisture during furnace operation. Condensation of excess humidity is not a problem in homes with lots of air leakage. It only becomes a problem when there is little air leakage to remove the moisture from the home—as is often the case in an energy-efficient house.

3. Ventilation

Building an energy-efficient, air-tight house may well lead to excess humidity build-up because there is not enough air leakage to remove the moisture. The sealed air-vapor barrier *must be complete* to keep moisture out of the insulation and walls. Excess moisture has no alternative then but to condense on cool window and wall surfaces.

To prevent a build-up of humidity, the well-sealed house needs controlled ventilation. Fans can be positioned in moisture-producing areas to exhaust humid air, and an inlet can be provided to bring in replacement air. If such fans are controlled with a humidistat (Figure 2-3), they will automatically keep the humidity at a comfortable level. As the moisture level rises, they will operate at higher levels. As the level drops, they will slow down to limit the amount of air (and heat) being exhausted.

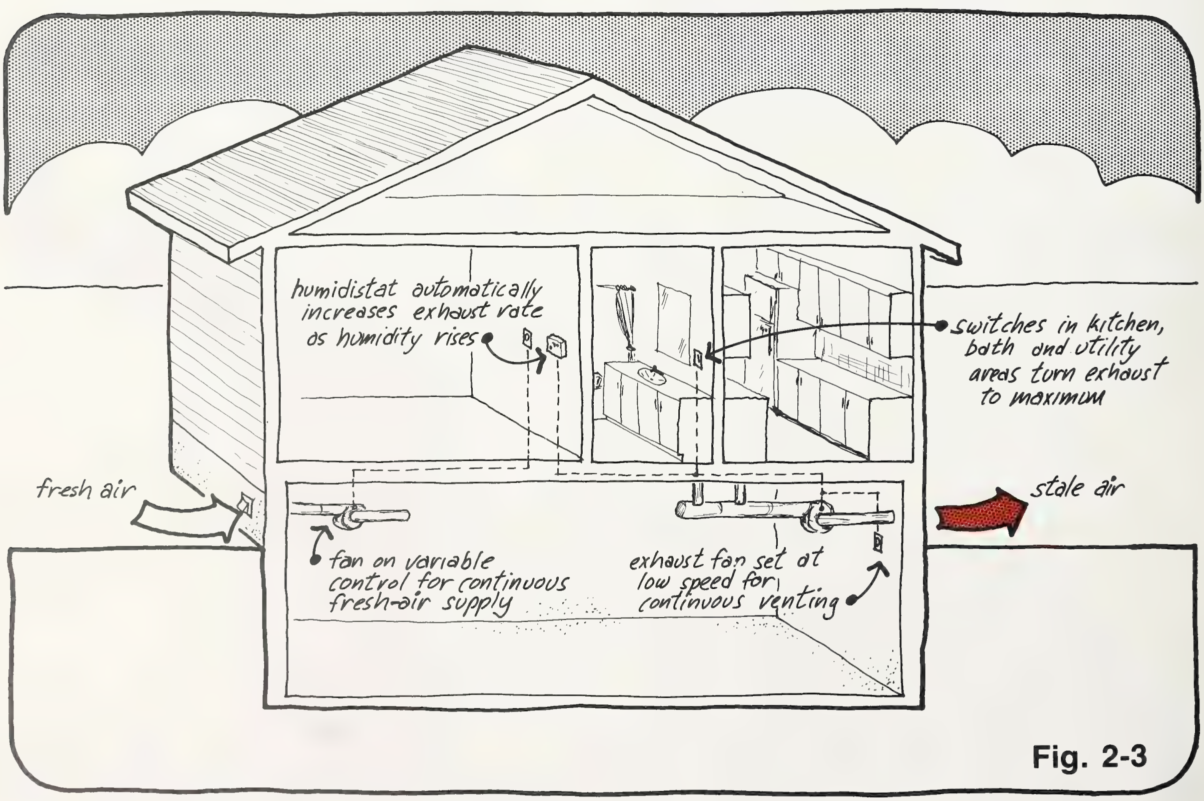


Fig. 2-3

B. Sealing The Energy-Efficient House

The construction of a well-sealed, energy-efficient home is the result of many small, careful steps. *The homeowner, designer, and contractor must work together* to ensure that each aspect of the house is designed, detailed, and built properly. Starting with the foundation, each successive assembly must join and be sealed such that the result will be the desired low-energy home.

1. Foundation

The importance of sealing potential cracks and joints at the foundation stage cannot be overemphasized. Because wood will, in time, shrink away from concrete, wherever these two meet an adequate, lasting seal must be provided.

The easiest method of ensuring a continuous air-vapor barrier around the joist space on top of the foundation wall is to install an *external* polyethylene strip (1000mm or 3' wide) during construction. This strip will be joined and sealed to the internal air-vapor barriers later in construction (Figure 2-4). This technique is used whether standard wood floor joists are utilized or floor trusses are substituted (Figure 2-5). The same technique is used for upper-level floor joists or trusses when a second floor is added.

Where a pressure-treated wood foundation is used, the same method is again employed. With this method, however, the air-vapor barrier is now *on the outside of the building shell.* To prevent condensation problems, some insulation must be placed on the outside of the barrier. Insetting the floor joist (Figure 2-6) allows a space for insulation on the exterior of the air-vapor barrier. (This matter will be dealt with in more detail later.)

2. Partition Walls

At points where partition walls join the exterior walls and ceiling, provision must be made to maintain the continuous air-vapor barrier. Strips of heavy 6 mil polyethylene, at least 450 mm wide (18''), are first attached to the exterior wall and between the double top plates of interior partition walls (Figure 2-7). These strips can then be sealed to the regular air-vapor barrier when it is installed after the wiring and plumbing are completed.

3. Windows and Doors

A rough opening space around window and door frames is required to ensure a level-and-plumb installation. By attaching and sealing a wide polyethylene strip (450mm or 18'') to the frame of the door or window before installation, the flap created can be sealed to the wall air-vapor barrier at a later stage (Figure 2-8). Loosely stuffed insulation in the rough opening space will provide a heat-flow barrier, and the sealed polyethylene strip will provide the air-flow barrier. Remember to leave sufficient extra length at the corners to allow the strip to be folded out flat against the wall.

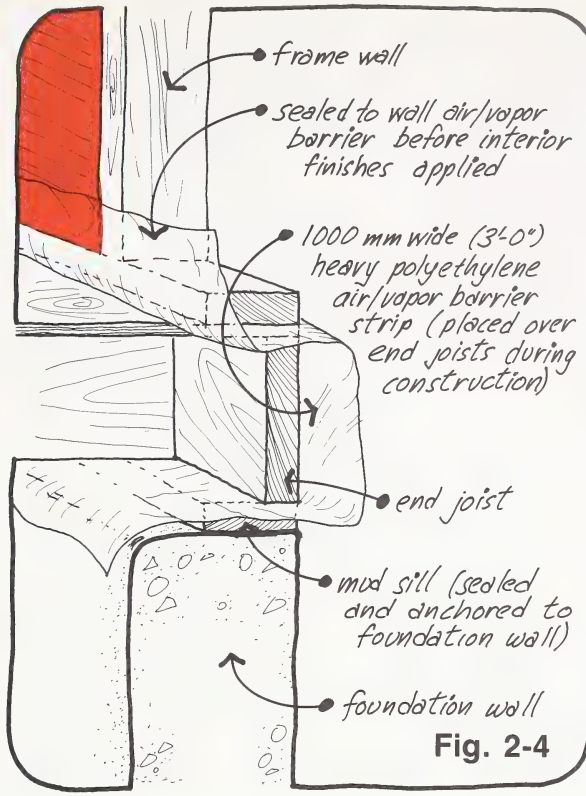


Fig. 2-4

4. Attic Access Hatch

An exterior ''door'' that is often overlooked is the access door to the attic space. The frame must be sealed to the ceiling air-vapor barrier to prevent air leakage. In addition, the hatch should be securely fastened with catches to prevent air pressure from lifting it off the weatherstripping seal (Figure 2-9). The hatch must also be insulated to a level of at least RSI 3.5 (R 20).

A better alternative is to place the attic access on an exterior gable end (Figure 2-10). In this location, it does not create a ''hole'' in the ceiling air-vapor barrier and is just as accessible as an interior hatch.

5. Chimneys and Flues

Metal chimneys and furnace flues must also be sealed to the ceiling air-vapor barrier although this presents special problems, because they expand and contract with heat. Metal firestops and sleeves are used to protect wood members and insulation from excess chimney heat. The firestops are sealed to the ceiling air-vapor

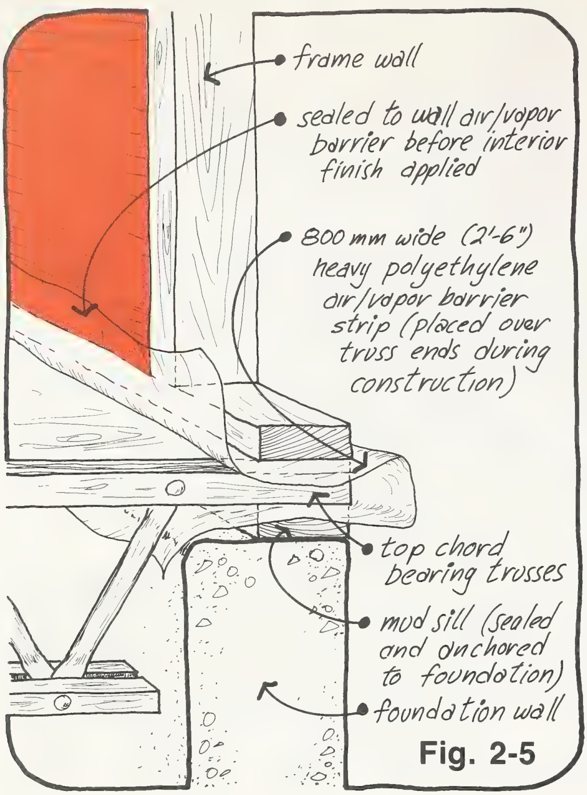


Fig. 2-5

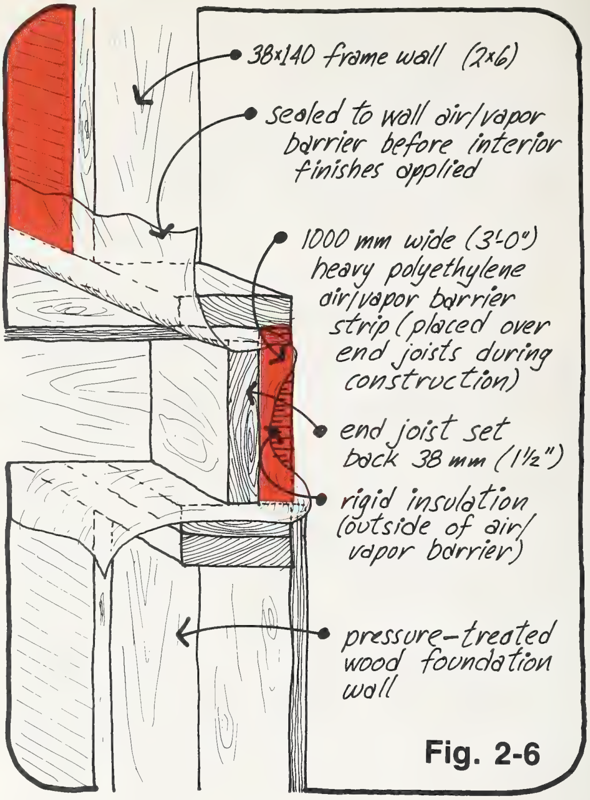


Fig. 2-6

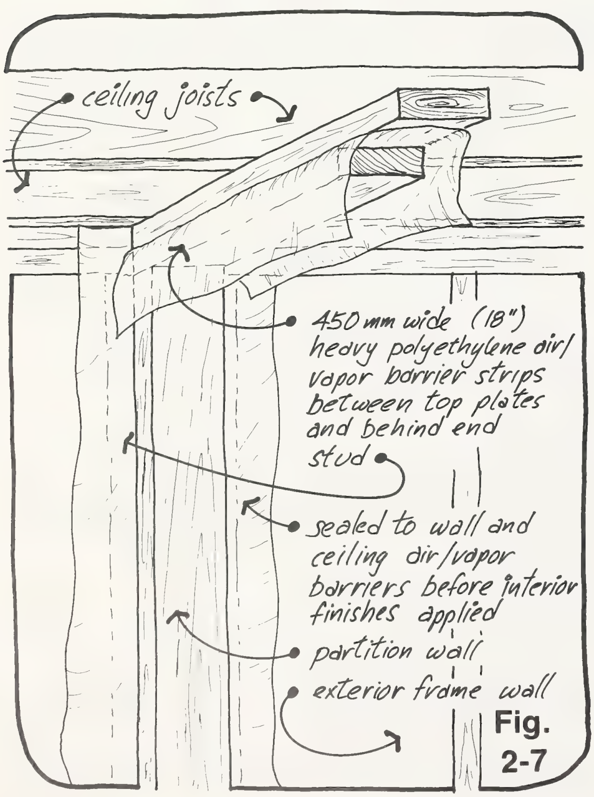


Fig. 2-7

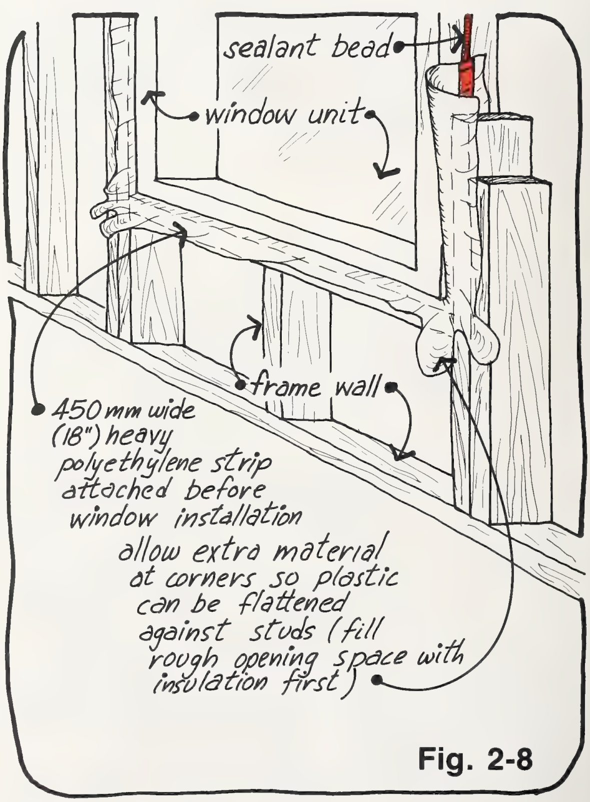


Fig. 2-8

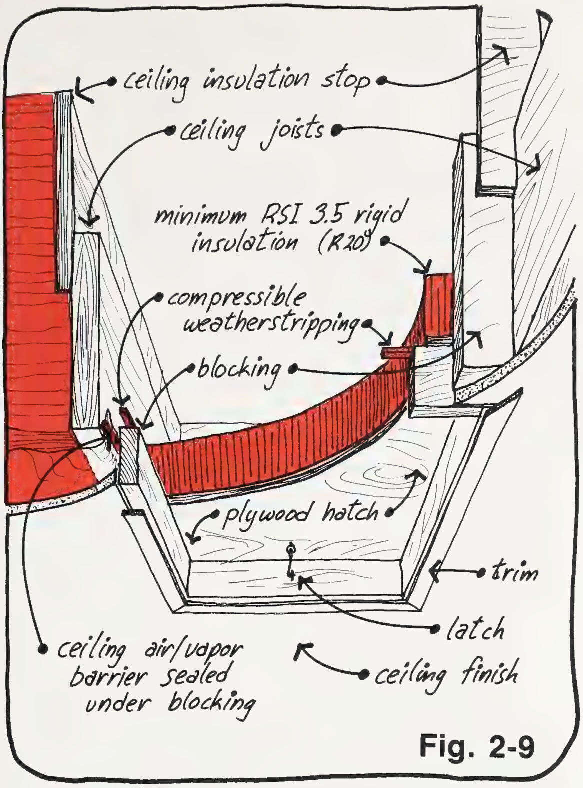


Fig. 2-9

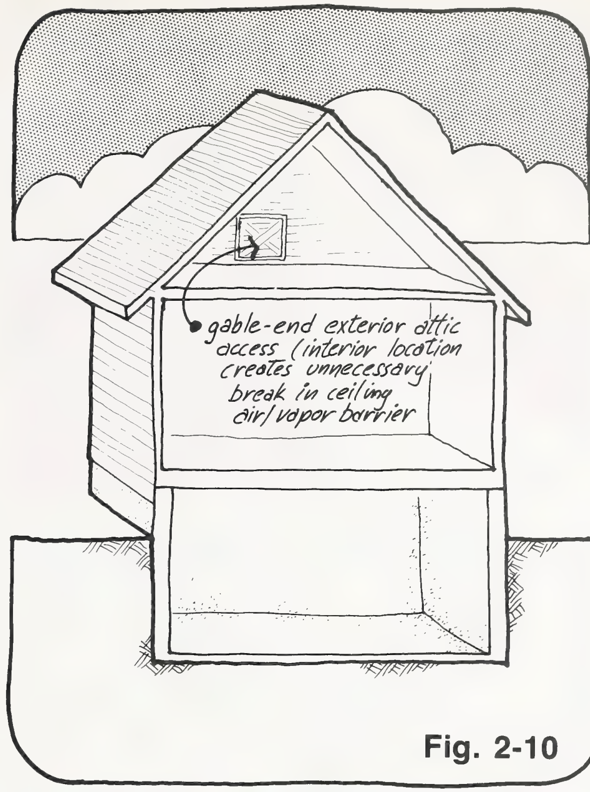


Fig. 2-10

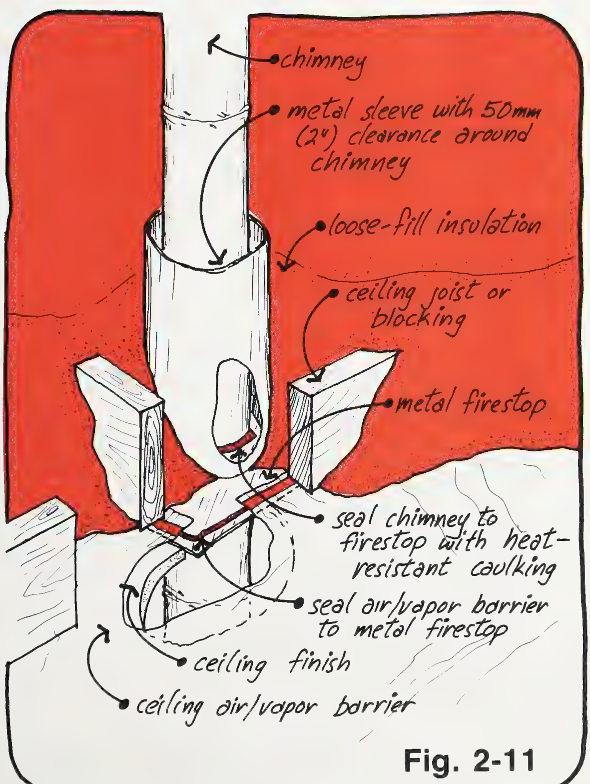


Fig. 2-11

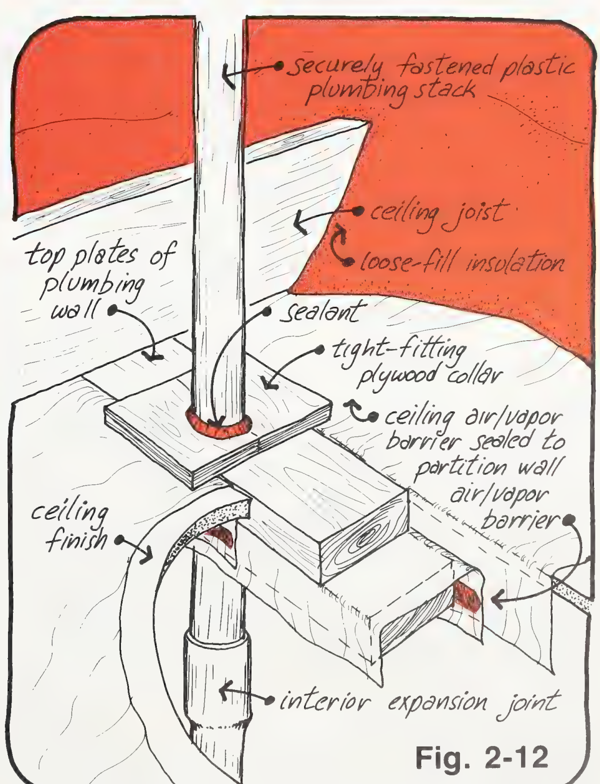


Fig. 2-12

barrier, and a heat-resistant caulking like muffler cement is used to seal the chimney or flue to the firestop (Figure 2-11).

6. Plumbing Stacks

Plastic and metal plumbing stacks and vents are also subject to longitudinal expansion and contraction as warm water flows through them.

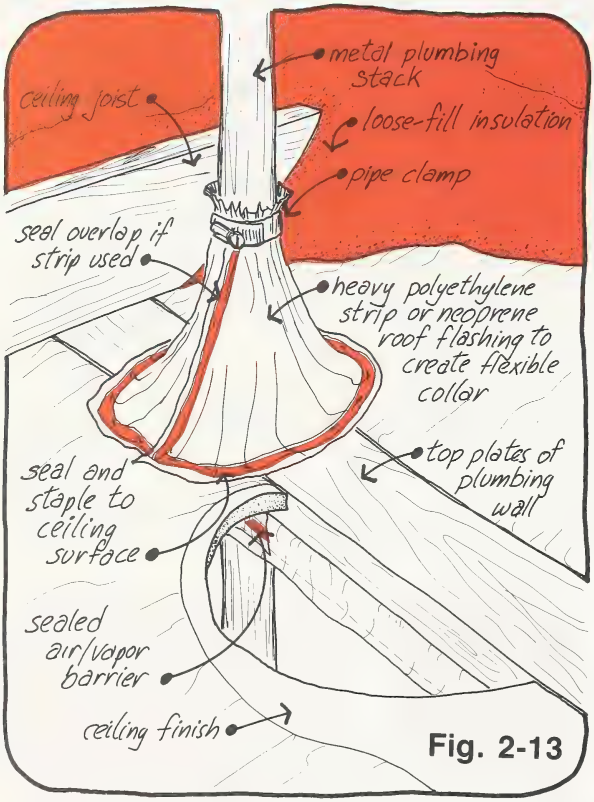


Fig. 2-13

They must either be securely fastened and sealed with an expansion joint installed to prevent movement or a flexible seal provided.

Plastic vents and stacks are best clamped at the ceiling level and sealed at that point (Figure 2-12). An expansion joint placed within the home will allow expansion and contraction in the line while not putting any pressure on the ceiling seal.

With metal stacks (copper or cast-iron), a flexible, gasket-type seal should be used. This can be a piece of heavy polyethylene or a neoprene roof flashing (Figure 2-13). Using a metal pipe clamp will ensure a tight durable seal around the pipe, and the base of the gasket can be sealed to the ceiling air-vapor barrier.

7. Electrical Fixtures

At each location of an electrical outlet, switch, or ceiling fixture, the continuous air-vapor barrier will be broken. Special outlet covers made of thick polyethylene, as shown in Figure 2-14, are available to help seal these spaces. The wall or ceiling air-vapor is sealed with caulking to the covers when it is applied, thus creating a continuous seal around and behind them.

An alternative to buying ready-made outlet covers is to wrap the electrical boxes in polyethylene. A 600mm square (2') piece of polyethylene is placed against the stud or joist prior to attaching the electrical box. The outlet box is nailed through the centre of the polyethylene, a slit made, and the electrical wire passed through (Figure 2-15). After taping the wire and polyethylene together, the excess film is stuffed into the box (wrapping it in a "bag"). After insulation has been carried out, the full wall or ceiling polyethylene sheets are extended completely over the electrical boxes. A small hole is made in the centre of the box, and the stuffed polyethylene is pulled through and folded flat onto the covering sheet. Caulking the two pieces together completes the seal of the electrical fixture box.

Yet another alternative is to build a sealed recess between any studs or rafters at locations where electrical boxes are required, or where items such as recessed soap dishes occur on walls. The wall cavity must still be insulated

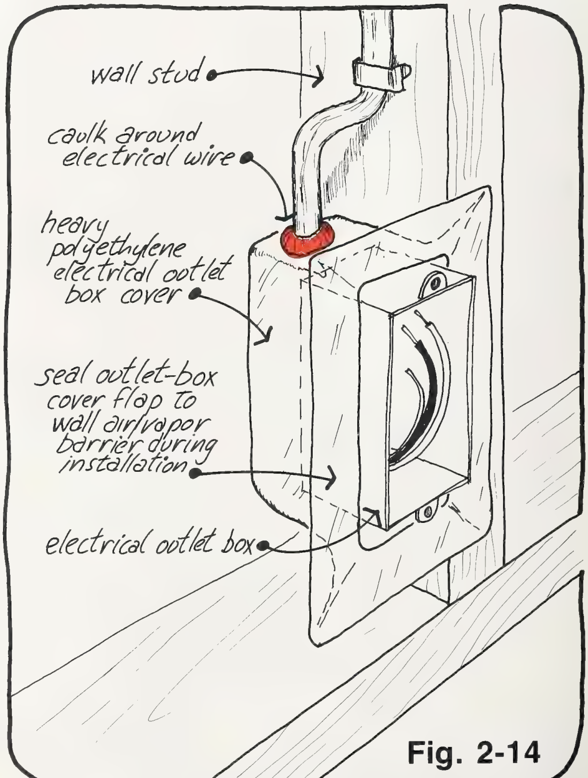


Fig. 2-14

around the box or fixture, but, as illustrated in Figure 2-16, the air-vapor barrier continues *unbroken* behind it.

C. The Isolated Air-Vapor Barrier

A number of different wall-construction techniques have evolved to isolate the air-vapor barrier so that mechanical services like wiring and plumbing do not have to penetrate it. The construction of these alternatives will be detailed later, but their principle of operation with respect to maintaining air-vapor barrier continuity is useful to note here. (Table 2-1 on page 16 gives standard metric sizes for building materials and framing spacing.)

1. Double Wall

In the double-wall construction technique, two walls are constructed with an insulated space between them. Using this technique, the air-vapor barrier is placed *on the outside of the interior wall* (Figure 2-17). If the wall is built with standard framing materials, an 89mm (3 1/2") wide cavity is created inside the polyethylene for wiring and plumbing. It can also hold a layer of RSI 2.1 (R 12) insulation. The cavity and outer wall are insulated to a level of *at least* RSI 4.2 (R 24). As a result, the air-vapor barrier is only one-third the way into the total insulation (from the warm side) and, most importantly, is not in the way of electricians, plumbers, drywallers, and finishers.

2. Interior Strapping

A second method of isolating the air-vapor barrier is with the application of interior strapping *on top of* the polyethylene, which is placed over a stud wall (Figure 2-18). If a ceiling or wall system with an RSI-value of 3.5 (R 20) is already in place, an interior strapping layer of 38 x 64mm (2 x 3), placed on edge, will create a plumbing and wiring cavity that can also be insulated to a value or RSI 1.4 (R 8) before the wallboard is attached. The total wall or ceiling insulation value will be RSI 5 (R 28) and, of course, can be much higher if wider studs or thicker ceiling insulation are used.

Summary

Creating a home that is airtight in order to reduce air-leakage heat loss is a job that is simple but one that must be attended to right from the start of design and construction. It may be difficult to find designers and contractors knowledgeable in the necessary techniques. However, the methods involved are becoming more readily accepted, and experienced tradespeople can be tracked down. And, of course, the concerned do-it-yourselfer can easily apply the solutions illustrated to create his or her own energy-efficient house.

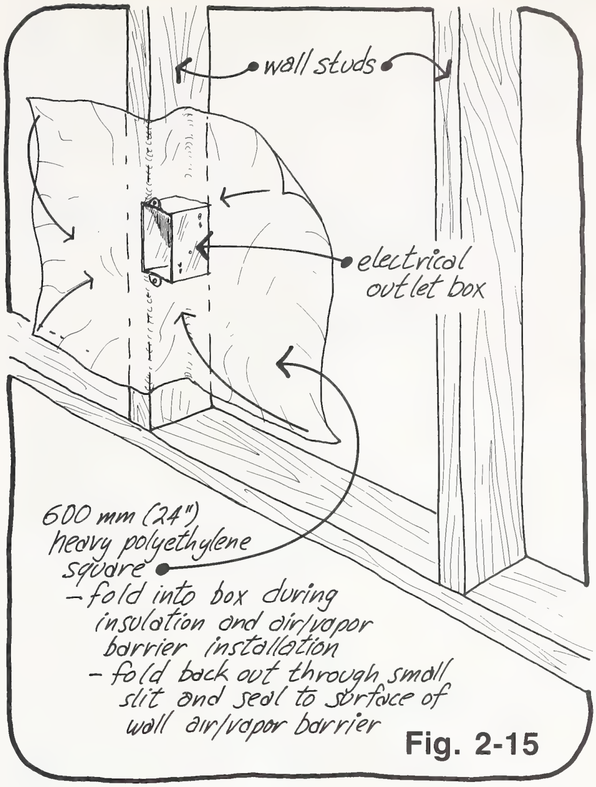


Fig. 2-15

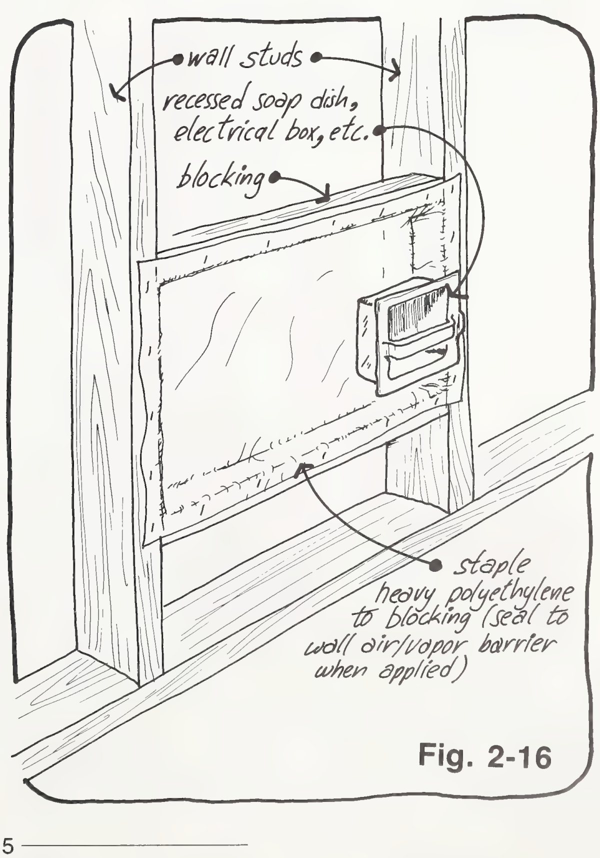


Fig. 2-16

Remember that it is important to become familiar with all aspects of air leakage. Methods of controlling it must be applied in the foundation wall, and ceiling assemblies. Details of sealing around all the parts that create "holes" (windows, doors, outlets, ducts, etc.) must be followed.

Care and diligence at this crucial stage of creating a well-sealed home will pay off many times over in lowered energy bills.

Table 2-1 STANDARDS FOR METRIC BUILDING MATERIALS

Material	Imperial Size	Metric Size (mm)
Dimensional lumber	2 × 2	38 × 38
	2 × 3	38 × 64
	2 × 4	38 × 89
	2 × 6	38 × 140
	2 × 8	38 × 184
	2 × 10	38 × 235
	2 × 12	38 × 286
Sheet sizes (Plywood, etc)	2 × 8 (feet)	600 × 2400
	4 × 8	1200 × 2400
Sheet thicknesses	1/4"	6
	3/8"	9
	1/2"	12
	3/4"	19
Stud, joist, or rafter spacing	16"	400
	24"	600
	32"	800

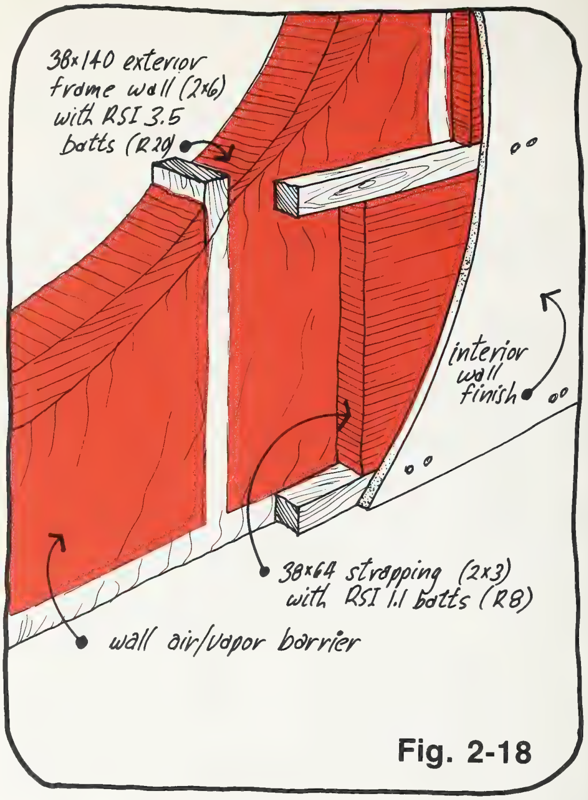


Fig. 2-18

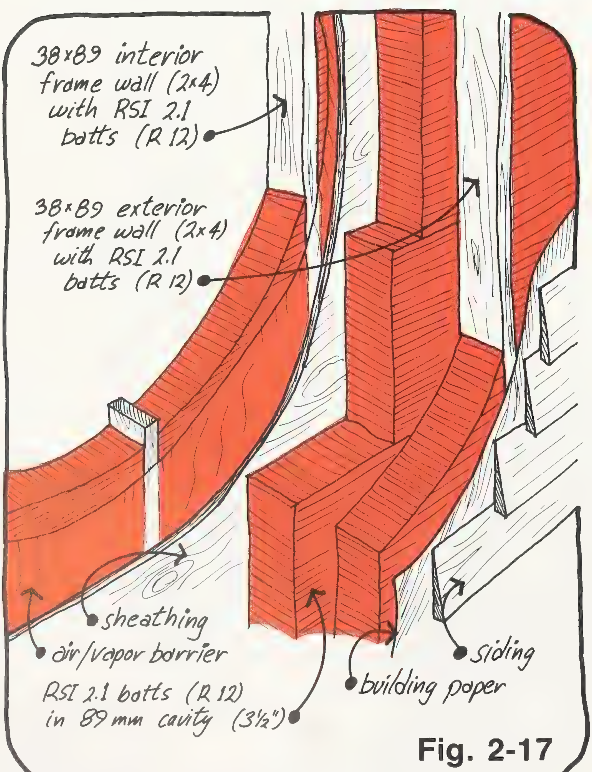


Fig. 2-17

NEW HOMES: MAKING IT COSY

OUTLINE

Heat losses by transmission through the building shell can account for 60% of the total loss from a home. Transmission losses occur when heat conducts, convects, and radiates through the walls, floors, ceilings, doors, and windows of a structure.

This program details what can be done in terms of using insulation to control transmission heat losses. Care and attention must be paid at all levels of construction to ensure that the exterior shell is adequately and completely covered with a thermal blanket—insulation. A number of ceiling, wall, and foundation systems are illustrated as solutions to attaining the high levels of insulation required in an energy-efficient home.

A. Insulation Materials

The value of insulation is measured in terms of its resistance to heat passing through it—its **R-value** in Imperial measurement or its **RSI-value** in metric terms. (Table 1-2, on page 1, gives common metric/Imperial conversions.) Insulation works by using air, which is an excellent insulator as long as it is not allowed to flow from warm to cold (convection). Convection is not a problem if the air is contained in small pockets: friction prevents it from moving readily. The best insulation materials contain many air cells in cavities created by very light materials such as paper, glass fibre, or plastic.

The resistance to heat flow of a building assembly such as a wall or ceiling is the sum total of the RSI- values of the layers (as illustrated in Figure 1-4, page 3). The resistance values of common building materials are given in Table 1-3 on page 4.

Insulation materials come in a number of forms. There are three basic types on the market: blanket, rigid, and loose-fill. Their individual characteristics and composition make certain types more applicable to certain jobs.

Blanket or **batt** type insulation, which is easy to handle, is a manufactured material made of either glass or mineral fibre. A very uniform product, it is made in specific thicknesses and widths to match common stud and rafter spacings. Blanket insulation materials are in the medium cost range and have an RSI-value of 0.6 per 25mm of thickness (R 3.5 per inch).

Rigid or **board** type insulation is also a manufactured product that comes in specific thicknesses and widths. It may be made of styrene, isocyanurate, urethane, or glass fibre. The insulation values vary from 0.6 to 1.3 per 25mm of thickness (R 3.5 to 7.5 per inch), and costs vary from moderate to expensive. It is important to remember that *any* plastic type of insulation must be covered with drywall or plaster if used on the interior of a living space.

Loose-fill types of insulation are suitable for use in non-standard or irregular joist spaces, as well as being quite inexpensive to use for flat ceilings. These products can be poured or blown into awkward spaces and are the lowest priced materials available. Loose-fill is made of mineral or glass fibre, plastic, wood or paper products. The RSI-values vary from 0.4 to 0.6 per 25mm of thickness (R 2.5 to 3.5 per inch). It is essential that paper or wood loose-fill insulations be treated for fire resistance.

B. Transmission Heat Loss

The movement of heat through any material is largely accounted for by conduction. The rate depends not only on the thermal resistance (or RSI-value), but also on the temperature difference between one side and the other. The greater the temperature difference between the inside of a home and the outside, the "faster" the heat will flow or be conducted out through the walls, floors, and ceilings. (The formula to calculate heat flow is given on page 4.)

Higher levels of insulation, that is, resistance to heat flow, will retard the flow but will never stop it completely as long as there is a temperature difference between inside and outside. (High insulation levels will also slow heat flow from outside to inside on hot summer days.)

Analysis has shown that the levels of insulation shown in Figure 3-1 are most beneficial for use in the cool climate zone of the Canadian prairies and of the midwestern United States. Note that the lowest levels are shown for below grade, because the earth never becomes as cold as the outside air in winter. In addition, slightly higher levels are shown for the ceiling because the warmest air in a home with poor air circulation will "sit" at that level (because hot air rises).

C. Attaining High Insulation Levels

There are a number of different foundation, wall and ceiling framing, and construction techniques available that will result in high insulation and airtightness levels. These will be illustrated in the next few sections of this program.

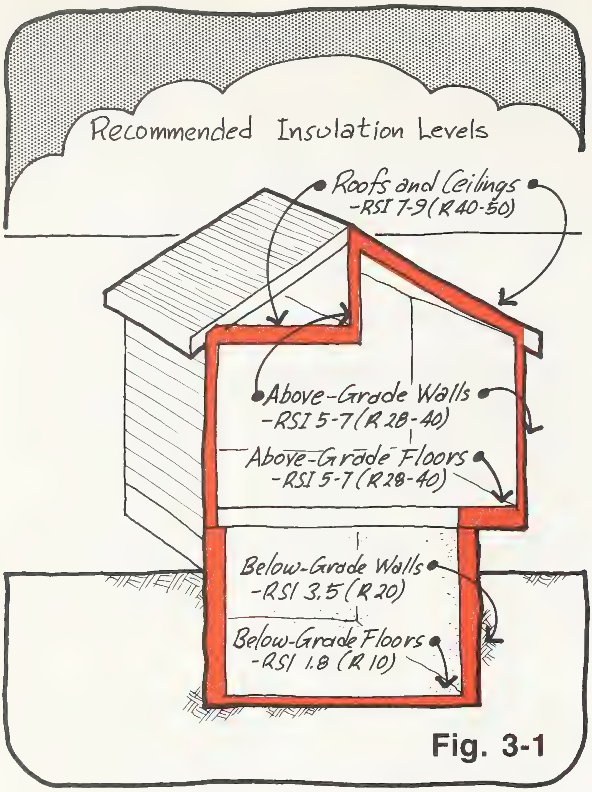


Fig. 3-1

It is at the design stage that the homeowner must decide which techniques to use. A combination of economics, expertise, and practicality will help make the final decision. Some designers are more familiar with certain construction techniques than others, as are contractors and building tradespeople. Some wall, ceiling, or foundation systems are more costly to build than others, yet may be faster to erect. The system chosen will depend on the time available to build or on the homeowner's ability to do the work rather than having to hire help. A number of factors, unique to each family, situation, and location, will determine the final building solution.

The following sections explain energy-efficient building methods from the foundation through to the roof. A review of the most common systems developed for energy-efficient homes will help answer some of the questions you may have when trying to pick a construction technique.

1. Foundation

Two main materials are used in foundation construction: pressure-treated wood, and concrete. Types of foundations include slab-on-grade, crawlspace, and full-height basement.

Slab-on-grade foundations are limited to concrete as a construction material and are most commonly used on flat sites where drainage may be a problem with crawlspace or full basement. As shown in Figure 3-2, heat loss is controlled by using insulation under the slab and around the perimeter. The insulation material must be suitable for direct earth burial—for example, extruded polystyrene. With this type of foundation system, it is important that all the services required are correctly installed *before the concrete slab is placed.* Changes or additions are extremely difficult to make at a later date. Services included in the floor slab may be forced-air ductwork, radiant heating coils, electrical conduits, plumbing supply and drainage lines, as well as telephone or sound-system wiring.

Crawlspace and full basement foundations can be constructed of either pressure-treated wood or concrete, or a combination of both. A **crawlspace foundation** is one with short walls and a limited space (usually 600mm or 2') under the *insulated* floor of the building above. A **full basement foundation** is similiar but provides a full-height, useable space under the *uninsulated* floor above.

Crawlspace foundation systems, illustrated in Figure 3-3, have their perimeters insulated to a level of at least RSI 3.5 (R 20). This further helps to reduce heat loss from the main building above. The building floor should be regarded as

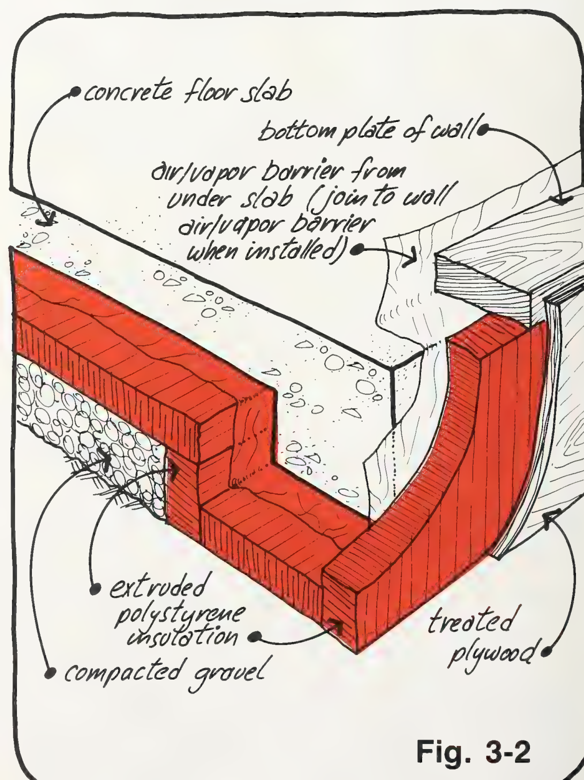


Fig. 3-2

an outside "wall" and, as such, should have an insulation value of RSI 5 (R 30). Local building codes may vary somewhat, but most require a moisture barrier—like building paper—placed as a ground cover, adequate cross-ventilation to keep the space dry during the summer, and some degree of heating in the winter to protect building services.

Full-height basement foundations are commonly used in many areas. They provide extra space for little extra cost, *but unless properly insulated and adequately sealed will greatly add to home heating costs.* Pressure-treated wood walls and a concrete floor create the lowest-cost complete foundation structure. The wood stud walls are easy to insulate with blanket insulation and convenient for installing the air-vapor barrier. Rigid insulation under the floor slab adequately insulates that area (Figure 3-4).

Although concrete foundation walls are initially cheaper to erect than pressure-treated wood, once they are insulated and sealed, the final cost becomes higher than their wood counterparts. If utilizing concrete foundation walls, there are two ways to insulate and seal them. Both exterior and interior methods have a number of advantages and disadvantages.

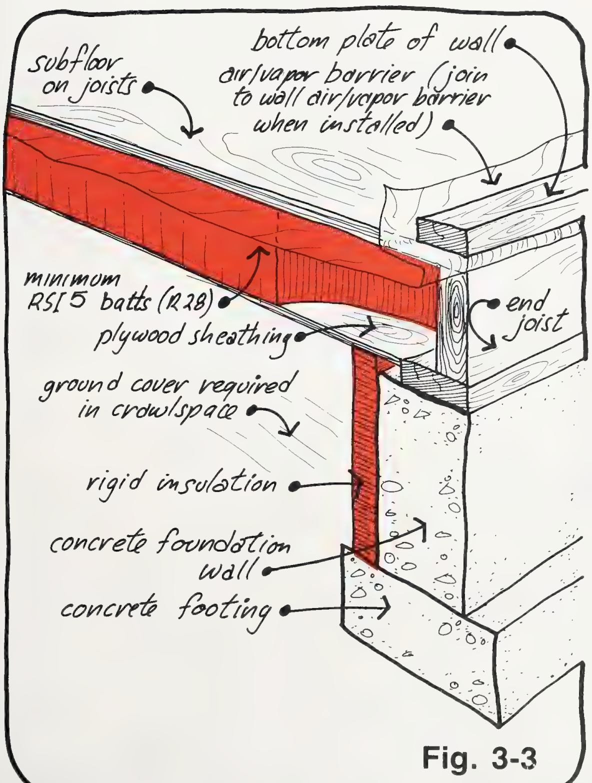


Fig. 3-3

Exterior wall insulation involves attaching rigid glass fibre or polystyrene sheets to the outside of the concrete walls before backfilling. These types of insulation are more expensive than batt types and must be protected above the ground line with stucco or pressure-treated plywood (Figure 3-5). One big advantage with this method is that the concrete mass in the foundation is included within the insulated house. This mass operates

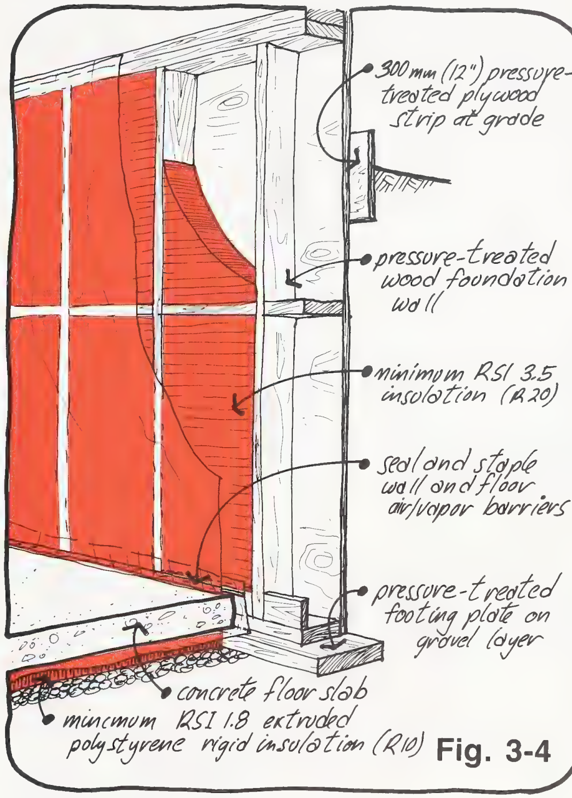


Fig. 3-4

like a thermal "flywheel", which tends to moderate temperature fluctuations in the house volume. A disadvantage is that some type of strapping is still required on the interior for air-vapor barrier and wallboard attachment.

Insulating on the interior of concrete foundation walls is more convenient and less costly to complete at a later stage of construction. Potential space is lost, however, and the concrete mass is isolated outside the building envelope. As illustrated in Figure 3-6, when applying interior insulation, it is important to provide a moisture barrier from the grade level down to the floor. Concrete is porous, and moisture that seeps through after a rainstorm or spring runoff must be kept out of the insulation.

It is advisable when utilizing this insulation method to use 38 × 64 (2 × 3) studs, placed about 75mm (3") *out from* the concrete wall surface. In

this manner, one layer of RSI 1.8 (R 10) batts can be placed horizontally between the studs and wall, with a second layer of RSI 1.8 batts fitted into the stud spaces. Placing the studs out from the wall will also create a level surface for the final wall finish.

2. Joist Space

The most critical aspect of the joist space is the air-vapor barrier placement and sealing (as explained on pages 7-12). It has to be installed *and protected* during construction for later attachment to the wall and foundation air-vapor barrier. Dimensional lumber floor joists are most commonly used for main and upper level floors (Figure 3-7). When insulating, you have to make sure that the polyethylene layer is *not more than one-third the way into the total joist space insulation value* (as described and illustrated in Figure 2-2, on page 7).

As shown in Figure 3-7, a mud sill must be used with a concrete foundation in order to incorporate the air-vapor strip. Casting the joists into the concrete—commonly called "beam fill"—makes sealing the joist space very difficult. It is a good practice to seal the sill to the concrete, using a caulking material or a manufactured plastic strip.

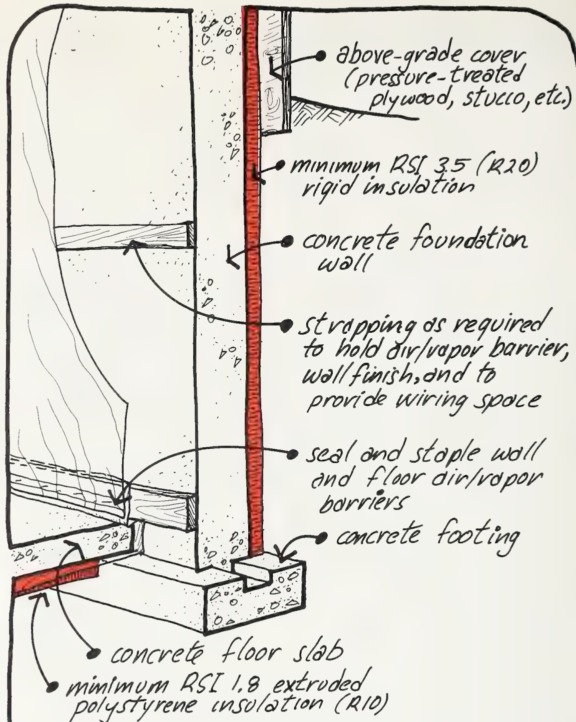


Fig. 3-5

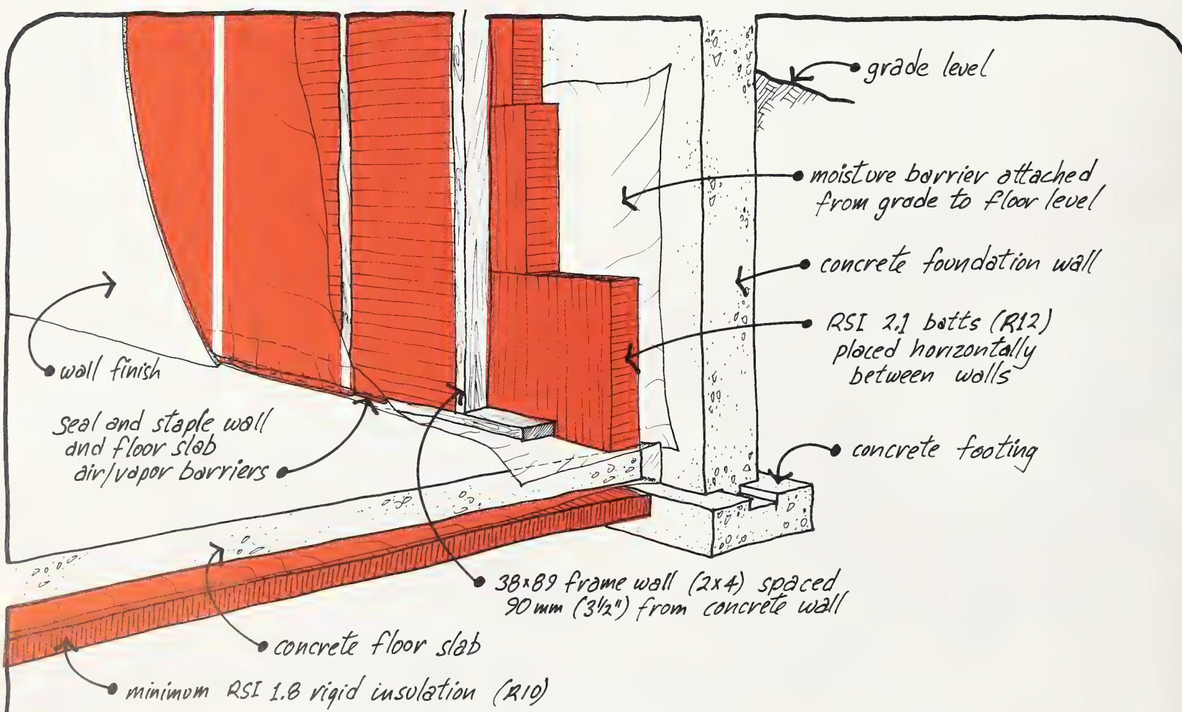


Fig. 3-6

Whether placing the floor joists on a concrete foundation wall and mud sill or on a pressure-treated wood structure, they can be recessed a few millimetres (Figure 3-8) so that more insulation can be placed *outside the air-vapor barrier.* The possible effects on the type of siding chosen also have to be considered. Other alternatives for insulating the joist space and siding types are shown in the upcoming illustrations for all construction options.

Many builders are using trusses as alternatives to plank-floor joists in an effort to provide a post and beam-free lower level space as well as a cavity for mechanical services. Top-chord bearing trusses are the most practical in terms of placing the air-vapor barrier and insulation (Figure 3-9). Trusses that rest on their bottom chord have construction details similar to dimensional lumber floor joists.

3. Wall Construction

To attain the recommended levels of insulation in the above grade walls, something much more than the standard 38 × 89 (2 × 4) wall is required. Wider, single-stud walls can be built, or they can be altered into staggered-stud walls to eliminate the heat loss through the studding (which has less resistance to heat flow than insulation). Exterior insulated sheathing or interior strapping can be applied to create more insulation depth. Spaced double walls can be constructed for even more insulation depth. Or exterior trusses can be installed over standard walls to add insulation space. Each of these options, of course, has advantages and disadvantages.

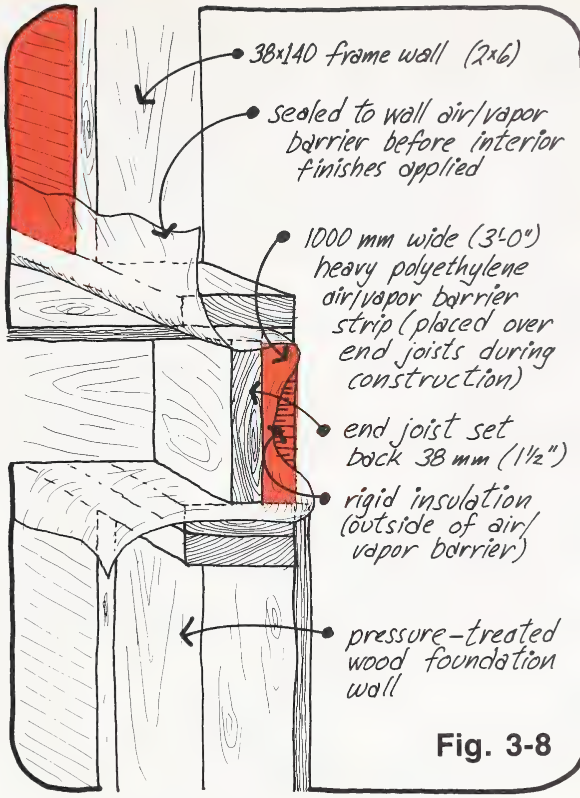


Fig. 3-8

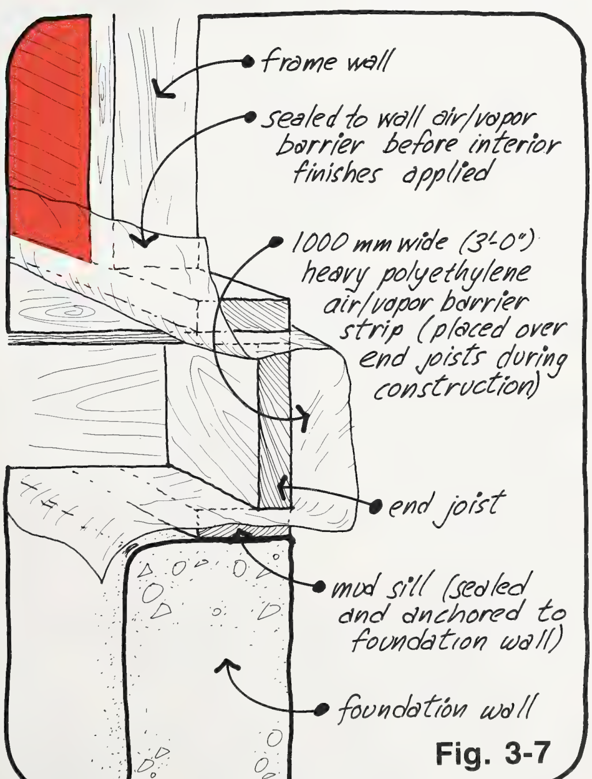


Fig. 3-7

a) Single-Stud Walls

To attain insulation levels of RSI 5 (R 30), a single-stud wall of at least 38 × 235 (2 × 10) must be constructed (Figure 3-10). Two advantages of this method are the opportunity to create well-insulated lintels over doors and windows and to overhang the bottom plate over the end joists to allow for more insulation. The stud walls are constructed in the same manner as normal 38 × 89 (2 × 4) walls, that is, built flat on the floor platform, then hoisted into place.

A major disadvantage of the method is that the wide studs offer "thermal bridges", or short circuits, for heat to flow through the wall, because wood is not good insulation. In addition, the air-vapor barrier is placed on the inside, where it is very susceptible to damage during construction.

b) Staggered-Stud Walls

An alternative to wide stud walls is to use the same width (38 × 235 or 2 × 10) of top and bottom

plates, but use 38 × 89 (2 × 4) studs alternately staggered inside and outside (Figure 3-11). Two layers of RSI 2.5 (R 14) insulation are used for thermal protection. This option offers the same main advantages as the wide stud wall but offers a better overall thermal performance (no bridges through the wall). However, the air-vapor barrier is *still on the inside and vulnerable to damage.*

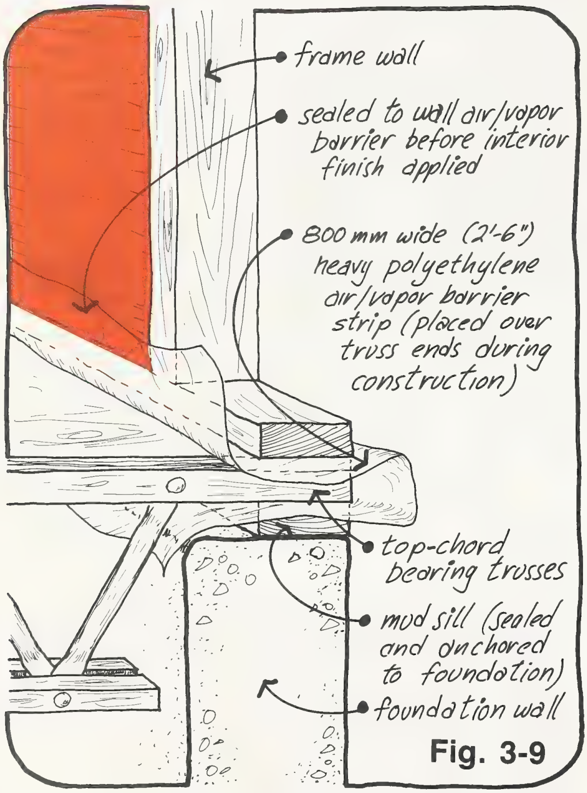


Fig. 3-9

c) Exterior Insulated Sheathing

Thinner stud walls (38 × 140 with RSI 3.5 insulation—2 × 6 with R 20) can be constructed and erected, then covered with an insulated sheathing on the exterior. Using 38mm (1 1/2") thick rigid insulated sheathing will result in a total RSI-value of 5 (R 30), and the entire wall structure is wrapped in insulation, thus preventing any thermal bridges through studs and lintels (Figure 3-12). The exterior sheathing can be rigid polystyrene, polyisocyanurate, or glass fibre.

Strapping may be required on the exterior, as well in order to attach siding over sheathing more than 40mm (1 1/2") thick. Nails alone will not provide enough holding power for siding if they must penetrate through more than that thickness. This type of insulated sheathing cover can be used over any type of wall system in order to increase its thermal resistance and to prevent the problem of thermal short circuits through studs. However, the crucial air-vapor barrier is *still exposed* to the work of electricians and plumbers on the inside of the wall.

d) Interior Strapping

To protect the fragile air-vapor barrier from damage during construction, servicing, and finishing, interior strapping can be applied horizontally over the inside of stud walls (after the polyethylene is in place). Figure 3-13 illustrates this technique. If the exterior wall is constructed with 38 × 140 (2 × 6) studding with RSI 3.5 (R 20) insulation, the interior strapping can be 38 × 64 (2 × 3) pieces placed on edge. Insulating the interior cavity, *after wiring and plumbing has taken place*, to a level of RSI 1.5 (R 10), will result in a total wall insulation value of RSI 5 (R 30). The air-vapor barrier is still within the warm one-third of the insulation (measured from the interior), so condensation will not be a problem.

If a 38 × 184 (2 × 8) exterior wall is used, 38 × 89 (2 × 4) strapping can be placed on edge over the air-vapor barrier. A total wall insulation value of RSI 7 (R 40) can be attained. Placing the interior strapping horizontally, as illustrated, facilitates wiring and the horizontal placement of drywall sheets. Installing the interior partitions *after the*

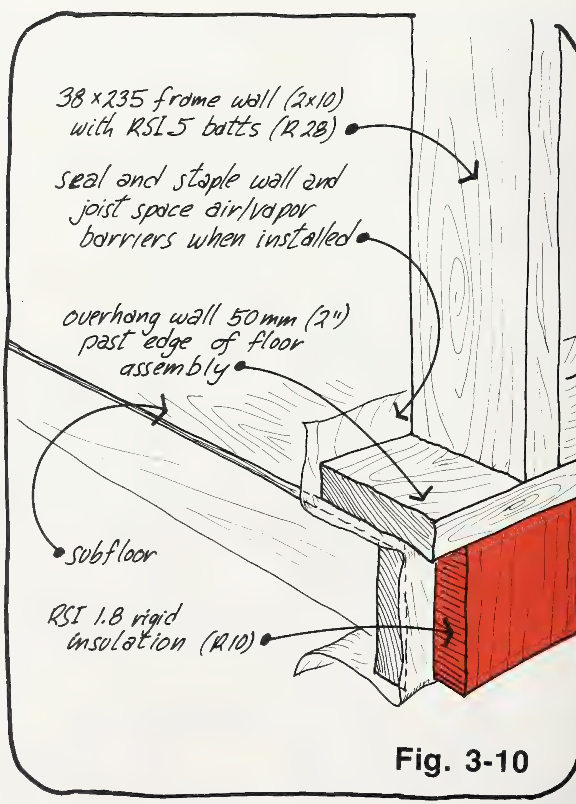


Fig. 3-10

strapping and air-vapor barrier are in place eliminates the problem of sealing the polyethylene "around" the wall and interior partition joints (as mentioned earlier).

e) Double Wall

To create an even wider space for insulation and still provide air-vapor barrier protection, the double-wall system was developed. A normal 38 × 89 (2 × 4) load-bearing stud wall is constructed with the air-vapor barrier placed *on the outside of the studs* (under the sheathing, as illustrated in Figure 3-14). This normal wall sits on the edge of the floor platform, contains the framed door and window openings, and carries the roof trusses (hence the term "load-bearing"). A cavity is left, then an *external* 38 × 89 (2 × 4) framing is attached to hold the exterior finishing material.

Leaving a 90mm (3 1/2") cavity and insulating all three spaces with RSI 2.1 (R 12) batts results in a total wall insulation value of RSI 6.3 (R 36). Leaving a cavity of 140mm (5 1/2") offers a total wall insulation value of 7.7 (R 44). In both instances, the air-vapor barrier is within the warm one-third of the wall.

This type of wall offers excellent air-vapor barrier protection during construction, contains a cavity of continuous insulation (eliminating thermal bridges), and has good joist-space insulation protection. It is, however, one of the most expensive wall systems to construct and requires a *very experienced* building crew.

f) Exterior Wall Trusses

Another method of adding an insulation "cavity" over a standard stud wall is to attach narrow, flat trusses to the exterior (Figure 3-15). The interior 38 × 89 (2 × 4) stud wall is again the load-bearing unit, with the air-vapor barrier *outside it* for protection during servicing and finishing. Adding trusses at least 200mm (8") thick will ensure the air-vapor barrier is in the correct position, and a total RSI-value of 7 (R 40) is attained.

Even deeper trusses can be used for higher insulation levels. In addition, the trusses can be placed *horizontally* to facilitate the attachment of *vertical* siding. One drawback to this system, however, is that the trusses do form thermal short circuits to the exterior, albeit not as substantial as full-width studs.

4. Floor Overhangs

A floor overhang can be considered as an exterior wall lying on its side and, as such, the same levels of insulation are required—RSI 5 to 7 (R 30 to 40). Usually, floor joists are at least 38 × 184 members (2 × 8), or larger, so adequate thermal insulation space is available. It is important to maintain the air-vapor barrier on the

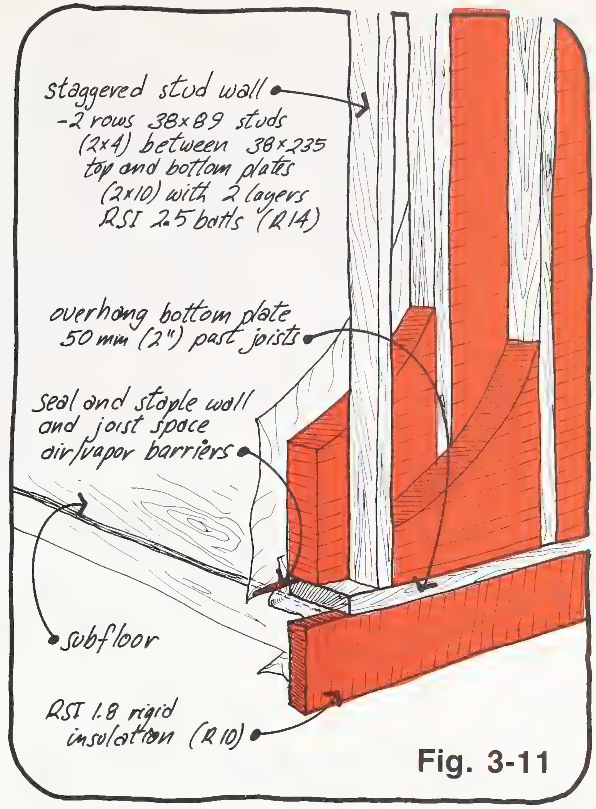


Fig. 3-11

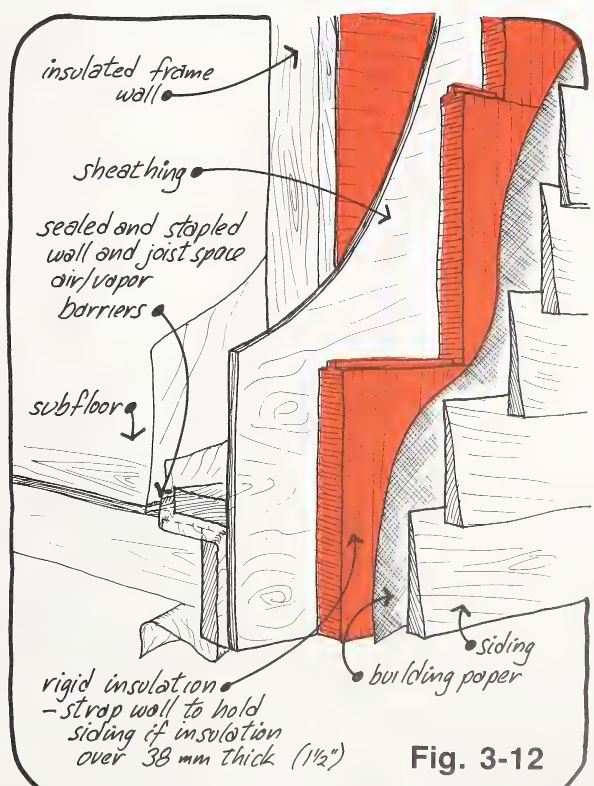


Fig. 3-12

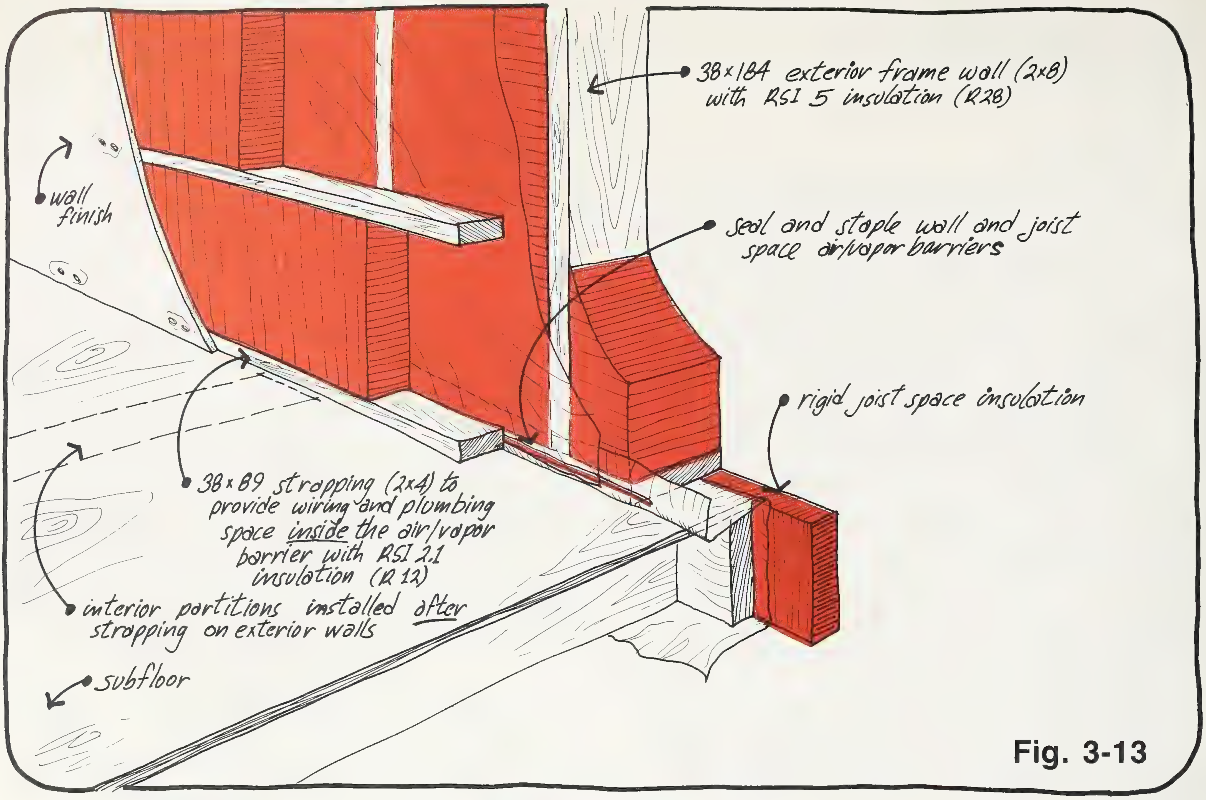


Fig. 3-13

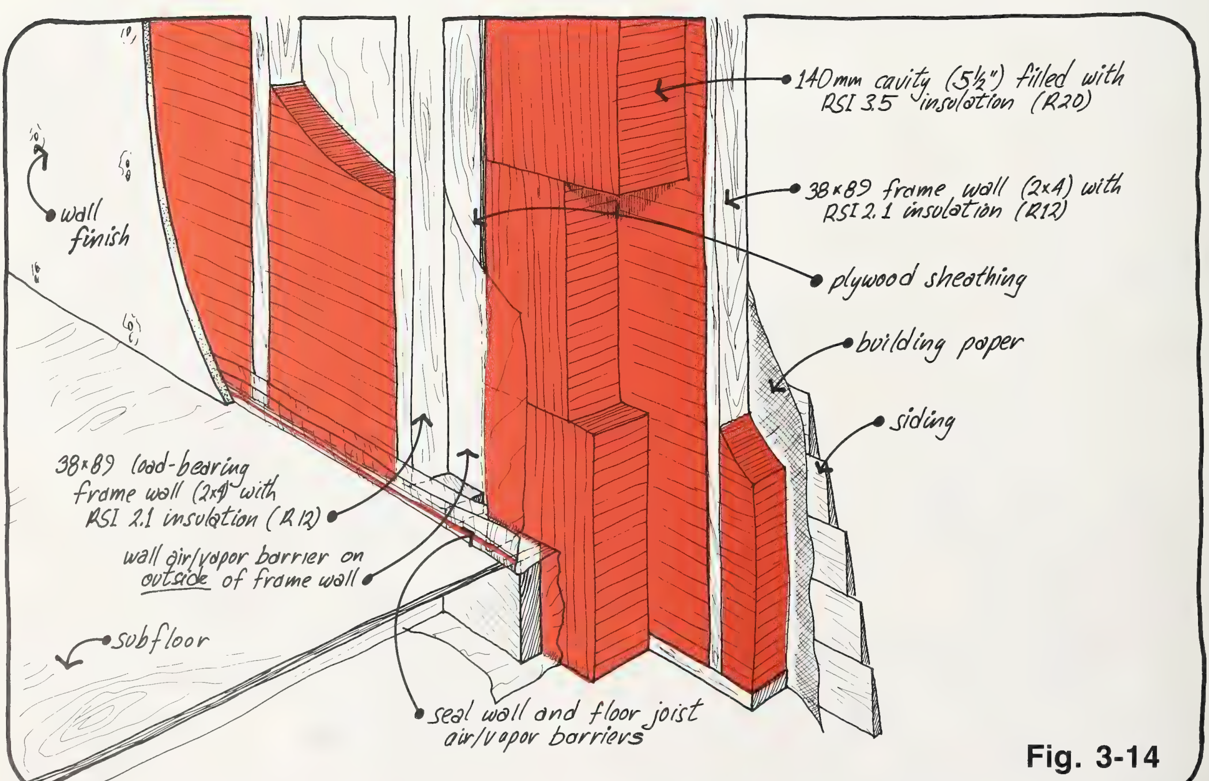


Fig. 3-14

correct (warm) side. Often this necessitates some expertise in sealing a number of small pieces of polyethylene (Figure 3-16).

The best solution to overhangs is to avoid them. Any extra or odd jogs in the exterior shell of a home create complexities in providing a complete insulation layer and a continuous air-vapor barrier.

5. Roofs and Ceilings

Two basic ceiling configurations are prevalent in home building: flat and sloped. A sloped ceiling does *not* have to be avoided in energy-efficient construction. The same high levels of insulation and airtightness can be achieved with the proper construction techniques. Ceilings should have an insulation level of at least RSI 7 (R 40).

a) Flat Ceilings

Flat ceilings are usually insulated with loose-fill materials and generally offer plenty of space to accomodate depths of 300mm to 400mm (12" to 16"). A problem has traditionally occurred at the eave—not enough depth for deep layers of insulation. The solution is revised truss design. A "high heel" type of truss can be constructed to accomodate deeper levels of insulation (Figure 3-17).

With any roof configuration, it is important to maintain adequate ventilation in the space above the insulation. Each 100m^2 of ceiling area requires 0.33m^2 of free ventilation area provided by soffit and roof or gable end vents (a 300:1 ratio or one square foot of vent for every 300 ft.^{2} of ceiling area). This ventilation keeps the attic space from overheating in summer and allows any condensed moisture to transpire out before ice is formed in winter.

Waxed cardboard, paper tube, or plywood baffles (as shown in Figure 3-17) keeps the loose-fill insulation from plugging up soffit venting. These materials should be used with batt insulation as well. If batt insulation is used for flat ceilings, two or three layers should be used (two layers of RSI 3.5—R 20—for example). The first layer can fit *between* the trusses, and the second layer is placed *perpendicularly* on top to form a gap-free blanket over the bottom truss chords.

High levels of insulation also tend to be quite heavy. Trusses should only be spaced at a distance of 400mm (16") centre to centre, and at least a thickness of 12mm (1/2") of drywall used on the ceiling. Placing the trusses farther apart, or using a thin finishing material, may result in sagging of the ceiling material after a number of years. Certain types of loosefill insulation are heavier than others, and manufacturers or dealers can calculate the density when given the desired RSI-value.

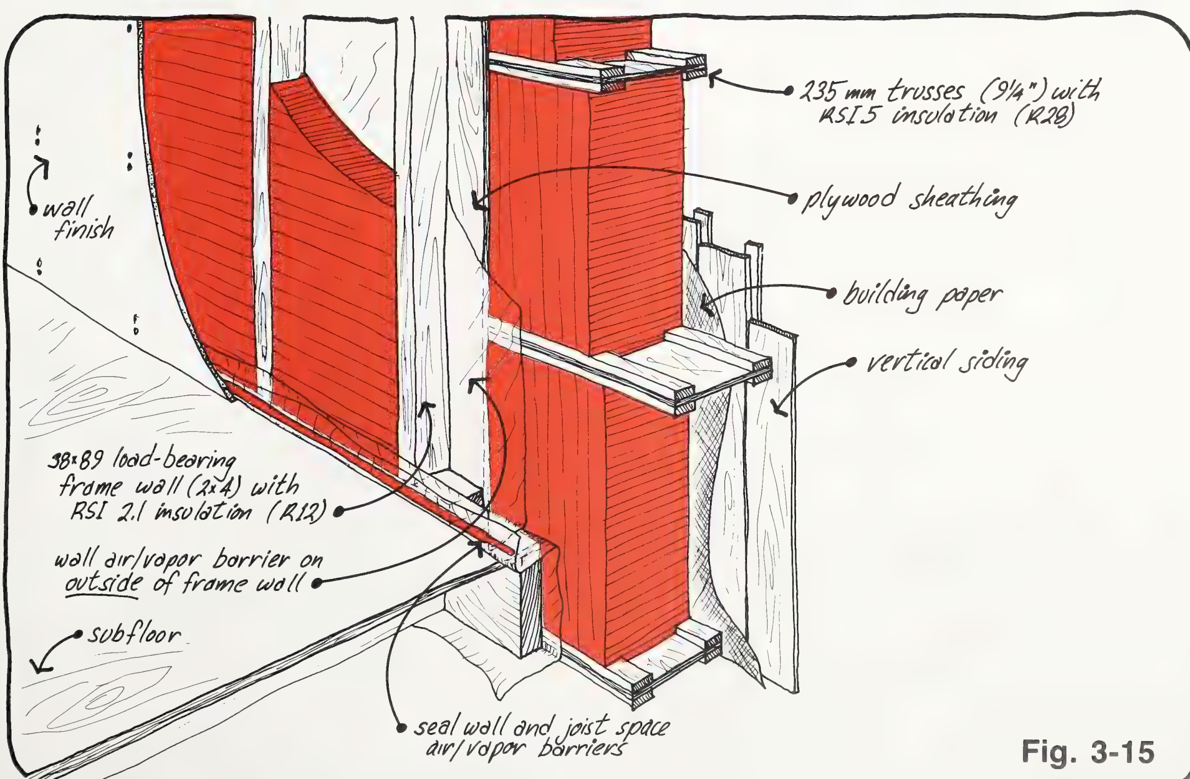


Fig. 3-15

One method of increasing the insulation value *and* providing air-vapor barrier protection is with interior strapping. The normal air-vapor barrier position would be under the ceiling finish, but, as illustrated in Figure 3-13, perpendicular strapping can be installed under the ceiling joists (just as it was over the wall studs on top of the polyethelene layer). This will now leave a convenient wiring space on the interior side of the air-vapor barrier. Because of high insulation levels in the attic space, the air-vapor barrier is still well within the warm two-thirds of the total insulation level.

b) Sloped Ceilings

The same high levels of insulation and airtightness must be reached in sloped ceilings as in flat. Wide roof rafters or trusses are used to provide the necessary depth for insulation (Figure 3-18). Again, strapping can be applied to the interior to increase the insulation depth and isolate the air-vapor barrier.

Leaving a small space of 25mm to 50mm (1'' to 2'') above the insulation (under the roof sheathing) and providing a continuous vent along each soffit and the roof ridge will ensure protection against any moisture condensation above the insulation. If an ''open beam'' effect is desired, false beams can be constructed under the well-insulated and sealed roof assembly.

6. Windows

Heat is lost through window openings in a variety of ways. It is conducted out through the glass and frame. Air-leakage heat losses occur past seals and weatherstripping. Good-quality, positive closing units will exhibit very low air-leakage heat losses. As shown in Figure 3-19, awning, casement, or hopper type windows (all swinging units) are the most efficient at closing tightly *and* keeping their seals over a long period of time. Sliding units tend to wear against the weatherstripping and lose their airtightness very quickly. Further, the closing action is not as positive as with a swinging unit.

Wood and hollow-cell plastic framing materials offer the most resistance to heat loss. Metal tends to conduct heat at an alarming rate and should be avoided.

The only option to adding insulation to the glazing is to add more layers of glass. It is the trapped air layers that add the thermal resistance (Table 3-1). For the best resistance value, there should be a minimum of 12mm (1/2'') of air between panes of glass.

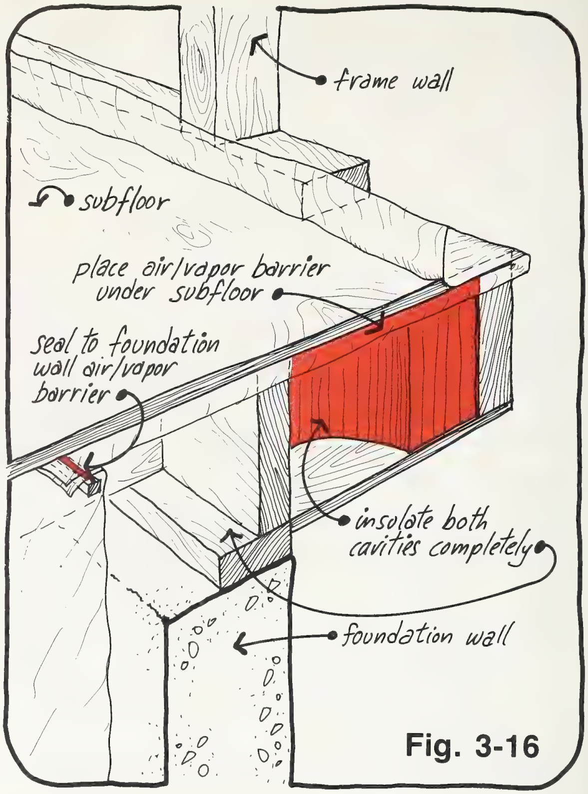


Fig. 3-16

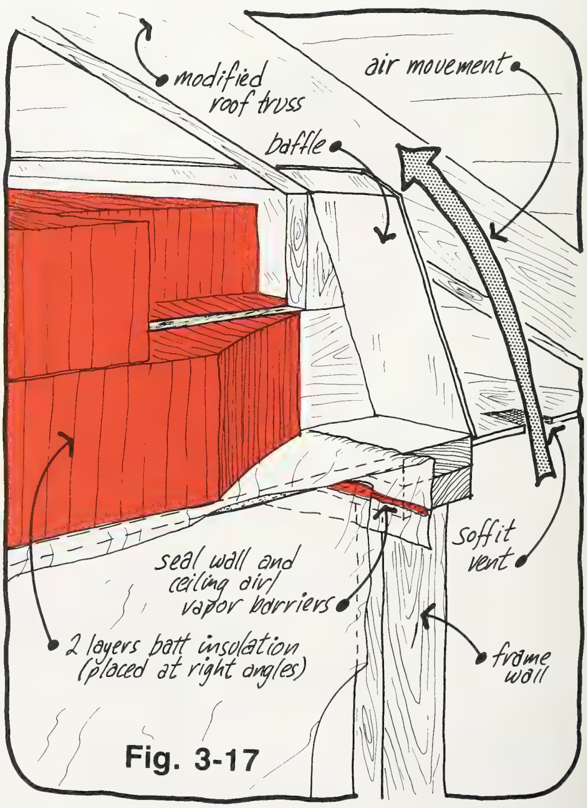


Fig. 3-17

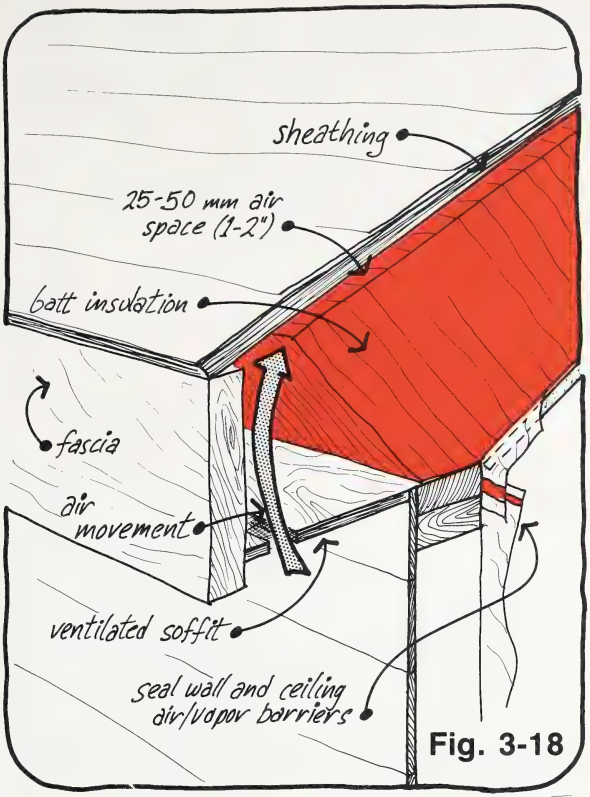


Fig. 3-18

Table 3-1 INSULATION VALUE OF GLASS

Number of layers of glass	RSI-value	R-value
One	0.15	0.87
Two	0.32	1.82
Three	0.49	2.77
Four	0.65	3.72

7. Doors

As with windows, doors rely on good-quality frame and weatherstripping materials to control heat loss. The door itself should have a core of wood or urethane foam for the best insulation value. Double doors, utilizing a tight fitting storm or a vestibule "airlock" (Figure 3-20), help reduce heat loss through this area of the home shell.

Summary

The principles of increased insulation and sealing potential air leaks must be applied to each part of the home's assembly. A *complete* insulation layer, plus a *well-sealed* air-vapor barrier, work together to reduce heat losses from energy-efficient homes quite drastically.

Walls and ceilings are obvious areas of insulation. However, the foundations, too, and the details of how these three components join together, need careful attention. Window and door selection also play a major role in deciding final energy-consumption levels in energy-efficient homes.

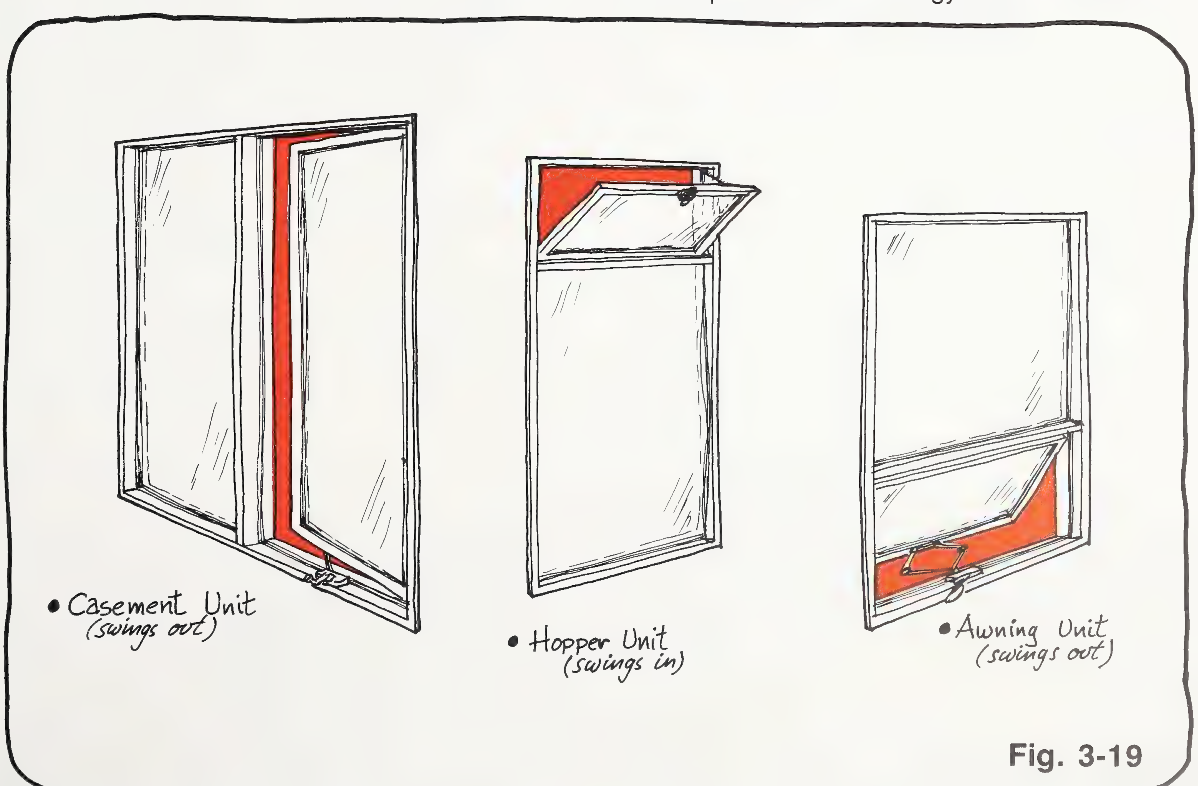


Fig. 3-19

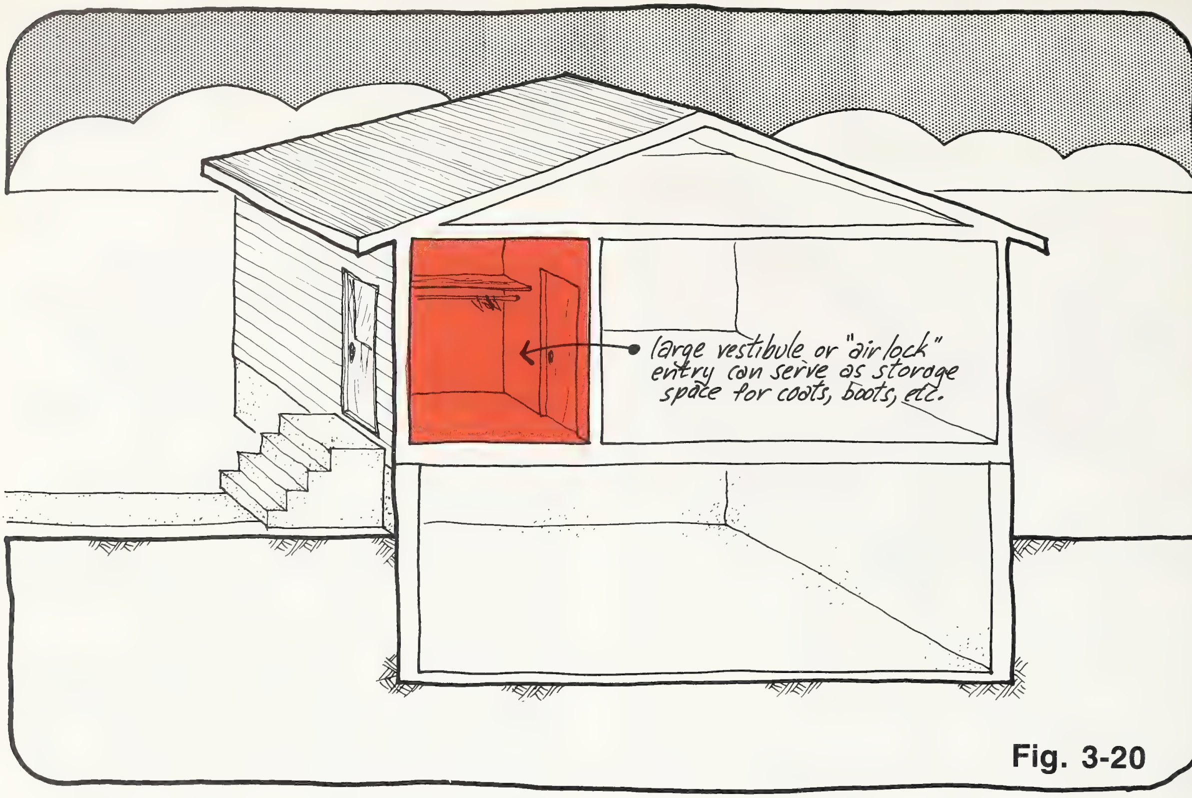

large vestibule or "air lock" entry can serve as storage space for coats, boots, etc.

Fig. 3-20

NEW HOMES: THE AIRTIGHT HOUSE

OUTLINE

Air leakage, the infiltration and exfiltration of air through the building shell, *can account for at least one-third of the total heat loss from a home.* Unless special precautions are taken during construction, this leakage occurs around windows and doors, through cracks in materials, past pipes, ducts, and conduits, up chimneys and exhaust vents, and around electrical fixtures.

This program reviews and clarifies some of the details concerning air-vapor barrier sealing that were mentioned earlier. All the building trades involved in construction should be familiar with the techniques for maintaining the integrity and continuity of the air-vapor barrier.

A. Air-Leakage Heat Losses

Uncontrolled air leakage through an inadequately installed air-vapor barrier is caused by the stack effect and by wind pressure. Hot air rises and is constantly trying to leak out of any cracks, joints, or holes near the top of the house (Figure 4-1). Cold air follows in through gaps in the lower part of the house to replace the lost warm air. This cold air is heated to room temperature, which causes it to rise and try to leak out—the stack effect. In addition, increased pressure on the exterior windward side of a home forces cold air in (Figure 4-2), while decreased pressure on the leeward side draws warm air out.

Air-leakage heat losses are often called "infiltration" because you can feel the cold air coming in, infiltrating through the building envelope. Since there is very little pressure difference between inside and outside, there is an equal amount of "exfiltration" of warm air. The warm air lost requires energy to heat it. Thus air-leakage heat losses can easily account for up to 40% of a home's total fuel bill.

B. Completing the Airtight Seal

Once the walls, floors, and ceilings of a home have been insulated, a final check must be done to ensure that all the wiring and plumbing has been completed. Where pipes, ducts, or wires penetrate the building exterior, polyethylene outlet covers or recesses must be properly sealed as well. Precutting the final wall and ceiling air-vapor barrier sections (leaving adequate extra for overlap) will make installation easier. A non-skinning sealant of an acoustical or solvent-based acrylic type is used to seal the pieces of air-vapor barrier together. *This must be done over a solid backing* (Figure 4-3), with staples to hold the polyethylene in place until covered with the final interior finishing material.

1. Ceiling Air-Vapor Barrier

Cut the ceiling air-vapor sections large enough to leave generous overlaps around the edges. (It is easy to trim excess polyethylene later, but very time-consuming to patch areas where not enough extra was left.) *Before installing the sheets*, apply sealant to the flaps of polyethylene along the interior partition and around electrical-fixture covers. Apply the ceiling sheet, being careful to press the sealed areas together, and apply staples at intervals of 200mm (every 8" as shown in Figure 4-4). Make sure that there is enough extra around the outside edges to make attachment to the wall polyethylene convenient.

2. Wall Air-Vapor Barrier

Again, precut the wall air-vapor barrier sections large enough to allow for generous overlaps. Before installing the sheets, prepare the individual areas that present sealing difficulties. The polyethylene strips that were attached to the door and window frames before installation must be folded out against the studs (Figure 4-5). Apply sealant along this flap, along the top and bottom plates, around any electrical-outlet covers and recesses, and down the edges of partition walls. Apply the wall polyethylene sheets, pressing along sealed areas and stapling at intervals as shown in Figure 4-4. Be careful to cut and patch completely around any breaks that are caused by pipes or ducts penetrating to the interior of the space.

3. Isolated Air-Vapor Barrier

Three techniques for building highly insulated walls and placing the air-vapor barrier part way through the insulation were illustrated and explained in Program Three: interior strapping; double wall; and exterior trusses (Figures 3-13, 3-14, 3-15). Using one of these techniques, most of the air-vapor barrier would have been attached and sealed *before* the wiring, plumbing, and application of the final insulation layer were completed. However, there are still areas that may require careful sealing before the interior finish is applied. Often, the base or top of the wall (Figure 4-6) must be caulked and stapled before the air-vapor barrier can be considered complete.

C. Interior Finishing

Whatever the method of construction used for the walls, floors, and ceilings, it is essential that the interior finishing materials (usually gypsum

wallboard) be installed carefully. Any holes that are required in the finish must be precut before the material is installed. No cutting can be done on the wall or ceiling since keyhole-type saws will puncture the fragile air-vapor barrier

When attaching the finishing materials, check that no nails or screws miss the backing framing—or a hole will be created in the air-vapor barrier. Any special backing that was applied for sinks, cabinets, or shelving should be marked on the wall finish so that the installers don't have to drill unnecessary holes.

D. Mechanical Ventilation

Energy-efficient homes will be quite airtight if they have been properly constructed and sealed. This results in the need for a mechanical ventilation system to keep the air in the home fresh, to hold down humidity levels, and to remove odors. In the past, standard homes had little need of ventilation because uncontrolled air leakage changed the entire volume of air in the home two or three times every hour. Energy-efficient homes, however, tend to have a natural air-leakage rate of only one-tenth of the volume per hour—sometimes even less!

To counteract the effects of a low, natural ventilation rate, mechanical fans can be installed

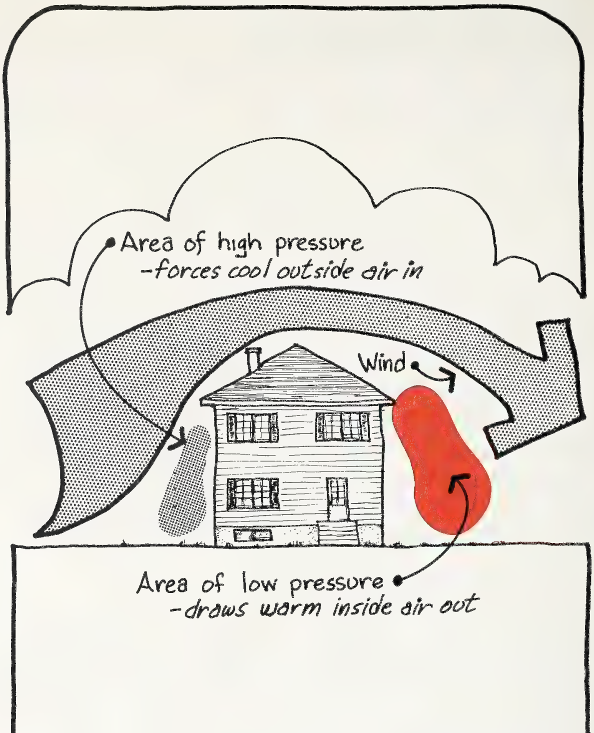


Fig. 4-2

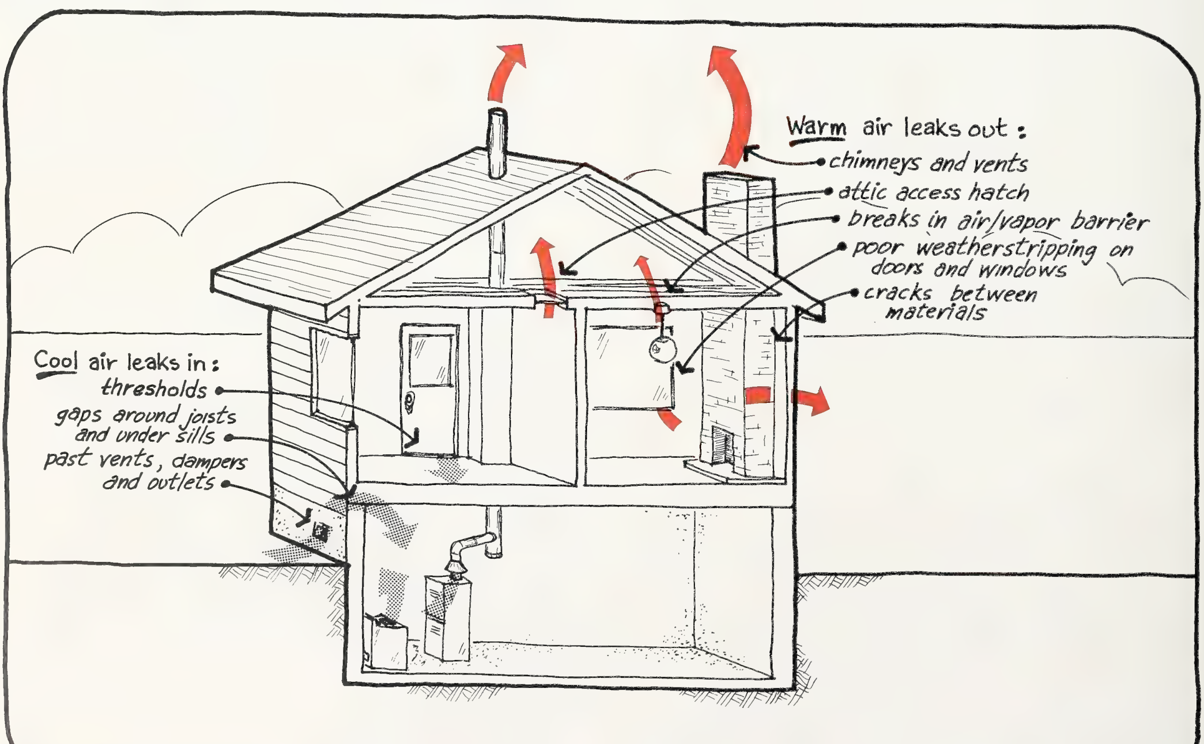


Fig. 4-1

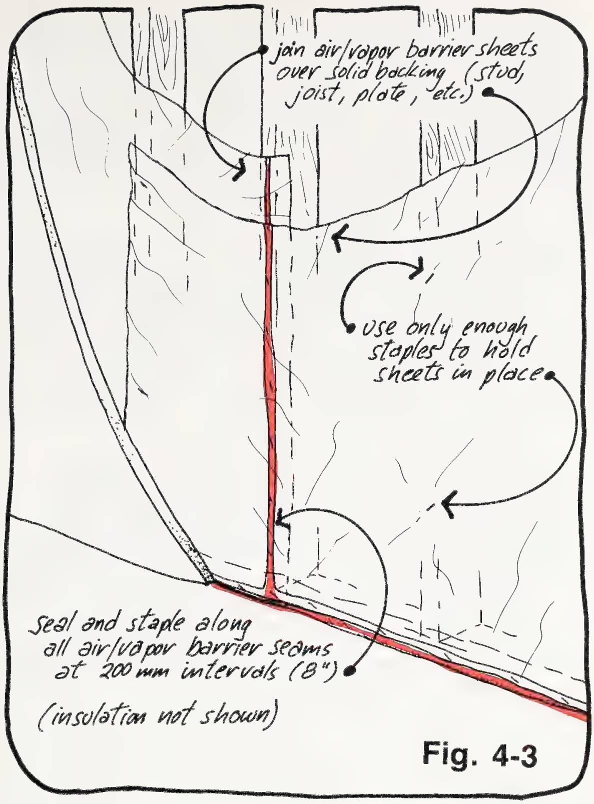


Fig. 4-3

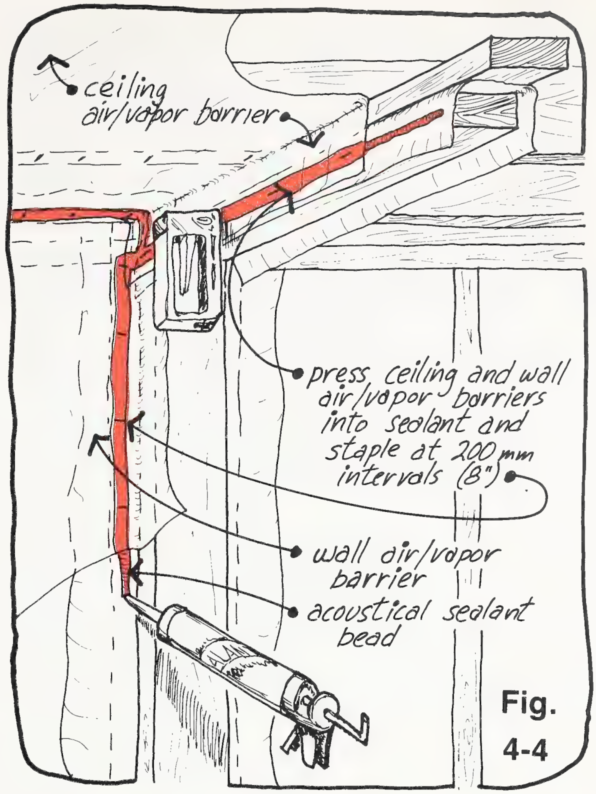


Fig. 4-4

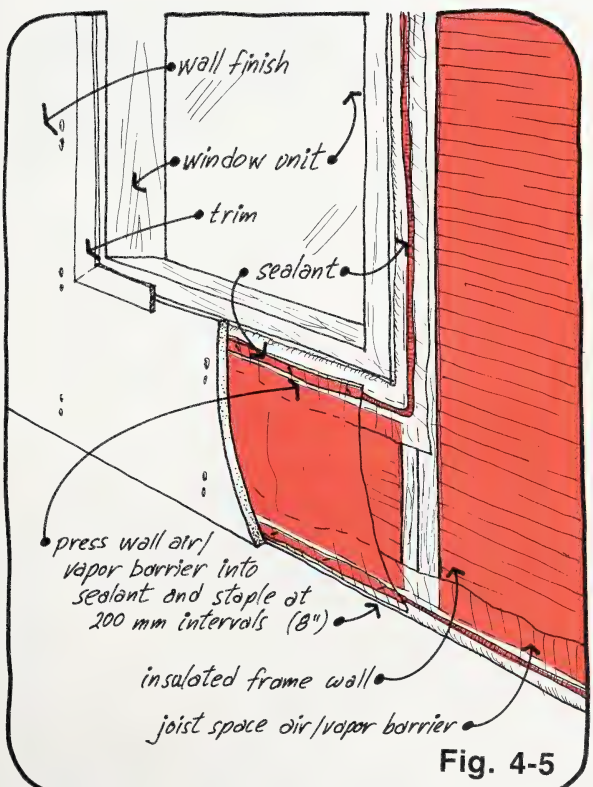


Fig. 4-5

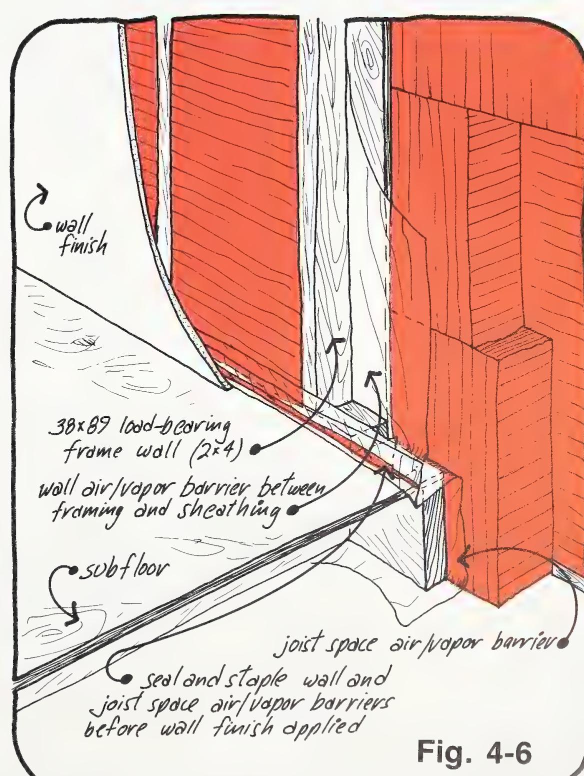


Fig. 4-6

to provide a controlled air-change rate. Humidity levels are the best indicator of a low ventilation rate. As the humidity rises, condensation on cool surfaces, such as window glazing, will occur. If the mechanical ventilation system is controlled by a humidistat (Figure 4-7), then a comfortable level of humidity can be set, above which the exhaust fan will automatically remove air to lower the level (replacing the humid air with drier, outside air). Override-type switches installed in bathrooms and laundry areas will provide short-term, high-velocity, air-exchange rates.

The separate kitchen, bathroom, and utility fans that exhaust through the ceilings of standard homes create many hard-to-seal breaks in the air-vapor barrier. In an energy-efficient home, these exhaust ducts are fed *down* interior partitions (Figure 4-8) and joined in a main exhaust duct that exits out the joist space. This means that only *one* exterior vent is required, and one large fan can provide enough ventilation for the whole home. And one intake vent—spaced at least 1800mm or 6' from the exhaust vent—plus one fan will feed fresh air into the home to replace the exhausted volume.

If a forced-air heating system is used in the home, fresh air will be evenly distributed throughout the structure during the normal furnace operating cycle (Figure 4-9). For radiant heating systems, a separate ventilation system may have to be installed in order to ensure the even distribution of fresh air (Figure 4-10).

E. Air-to-Air Heat Exchanger

Although mechanical ventilation may be required to keep the air in a home dry and fresh, a large amount of heat is lost when humid, stale air is exhausted. By installing an air-to-air heat exchanger in the exhaust/intake lines of a ventilation system, 60% to 80% of this waste heat can be retained in the home.

A simple, schematic air-to-air heat exchanger operation is shown in Figure 4-11. One fan is used to draw warm, humid, stale air from the home and pass it through the exchanger, where it gives up most of its heat before being exhausted. Another fan draws in cool, dry, fresh air from outside to replace the exhausted air. This fresh air picks up most of the heat from the exhaust air in the exchanger.

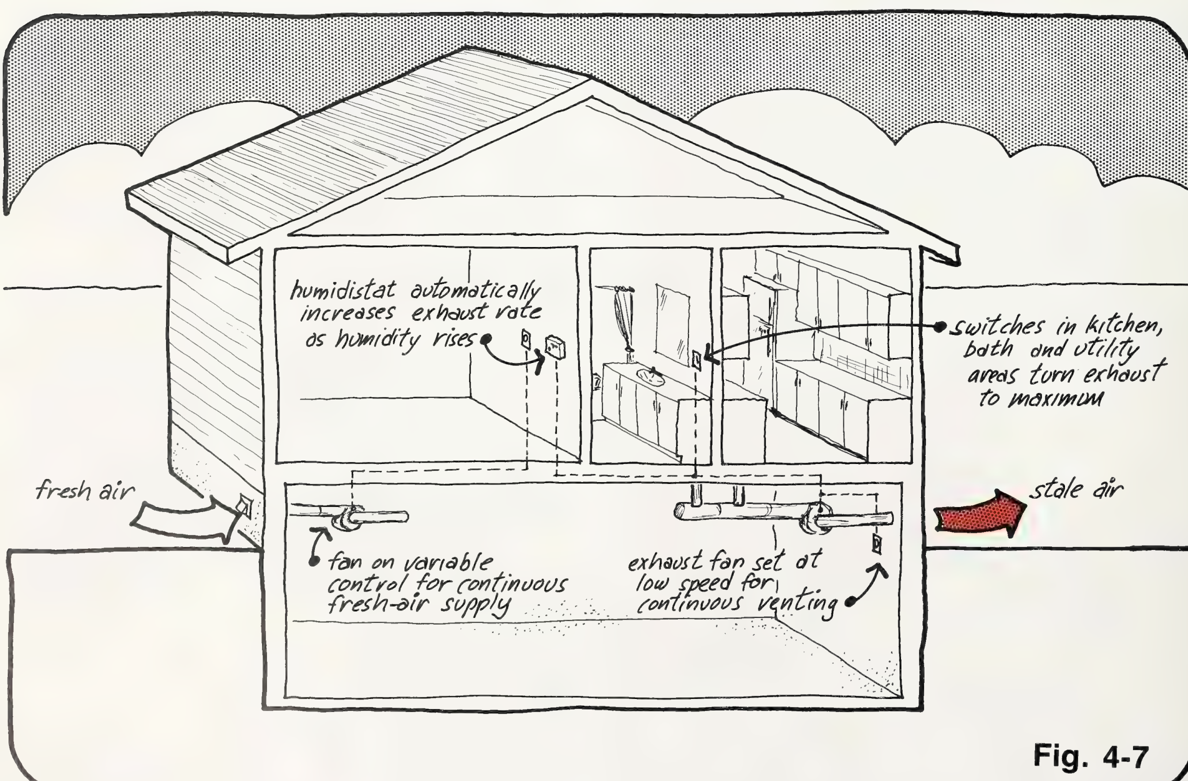


Fig. 4-7

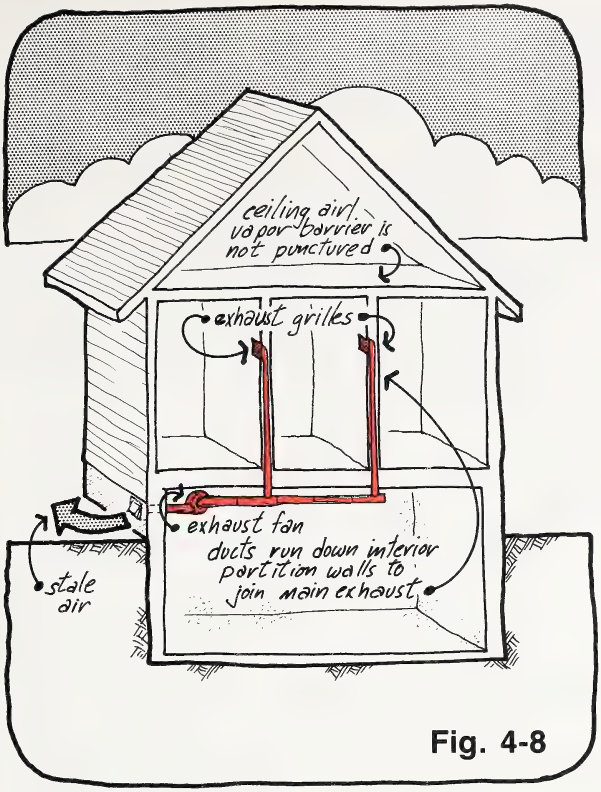


Fig. 4-8

Air-to-air heat exchangers are made up of many channels. The exhaust air travels in one direction in every second channel, and the incoming air travels in the other direction in the alternate channels. As the air flows pass each other, the warmer stream transfers heat by conduction to the colder streams on either side.

Logical areas to locate exhaust grilles (Figure 4-12) are bathrooms, laundry rooms, and kitchens. Clothes dryers and range vents should *not* be directly connected to an air-to-air heat exchanger, because lint and grease will quickly plug up the small air channels.

Fresh, warmed air from the exchanger can be distributed in the home by one of the methods illustrated in Figures 4-9 and 4-10 (depending on the type of heating system in the home).

Summary

Applying the finishing touches during construction to create an airtight house is a simple but time-consuming task. Attention to details of sealing must be done or all the preliminary aspects of controlling air leakage around openings, through electrical outlets, or past pipes and ducts will be to no avail. The methods illustrated in this program, and in Program Two, can easily be applied by the

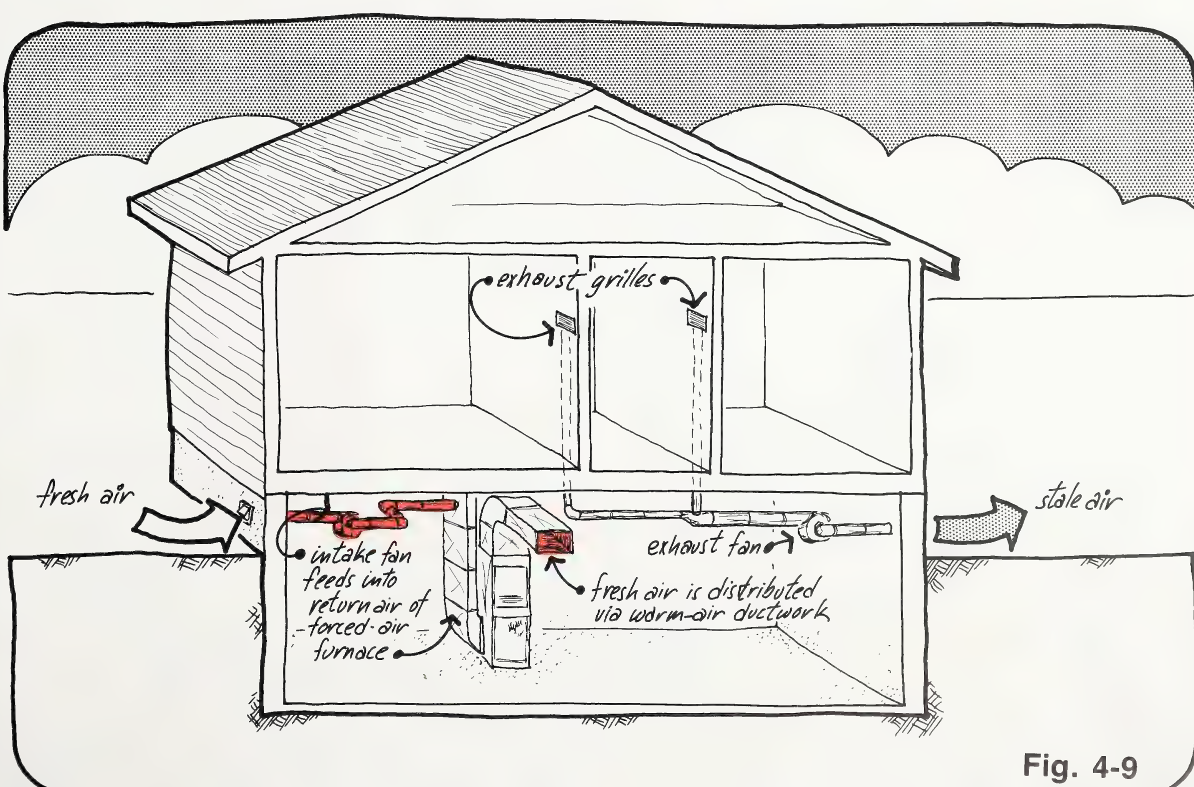


Fig. 4-9

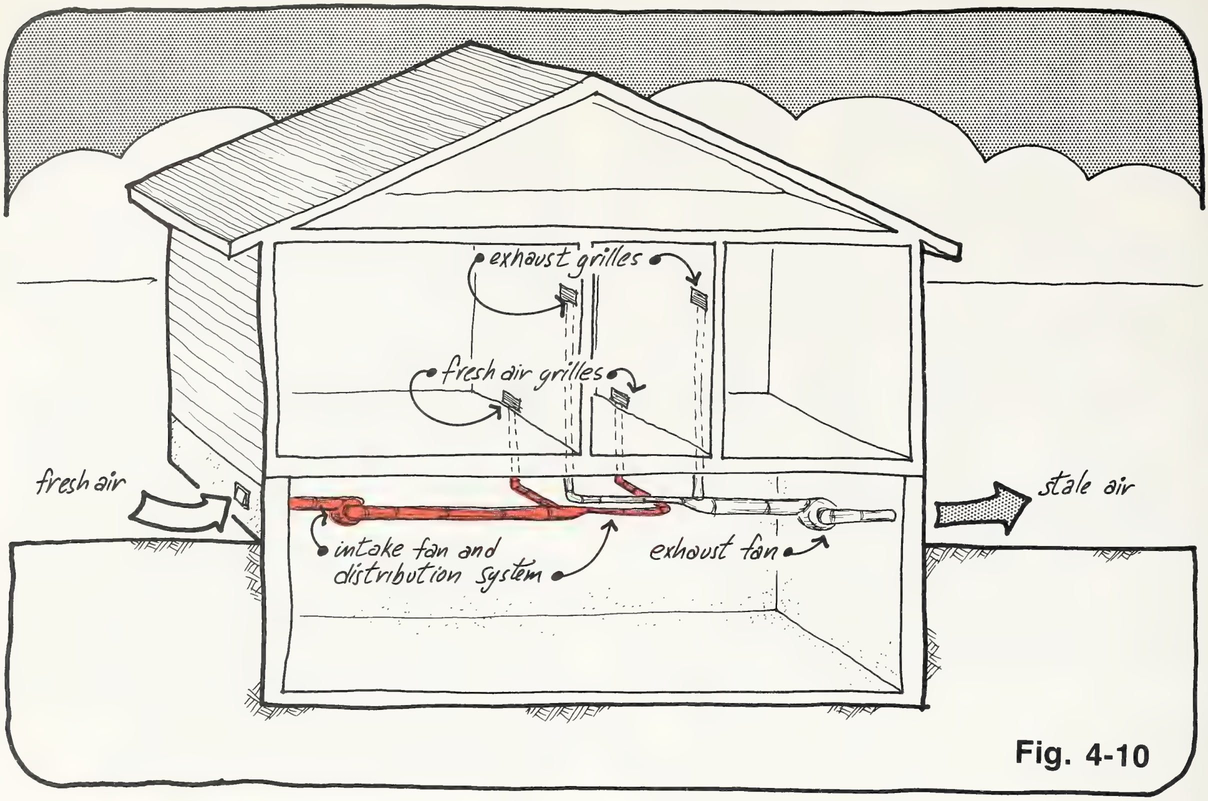


Fig. 4-10

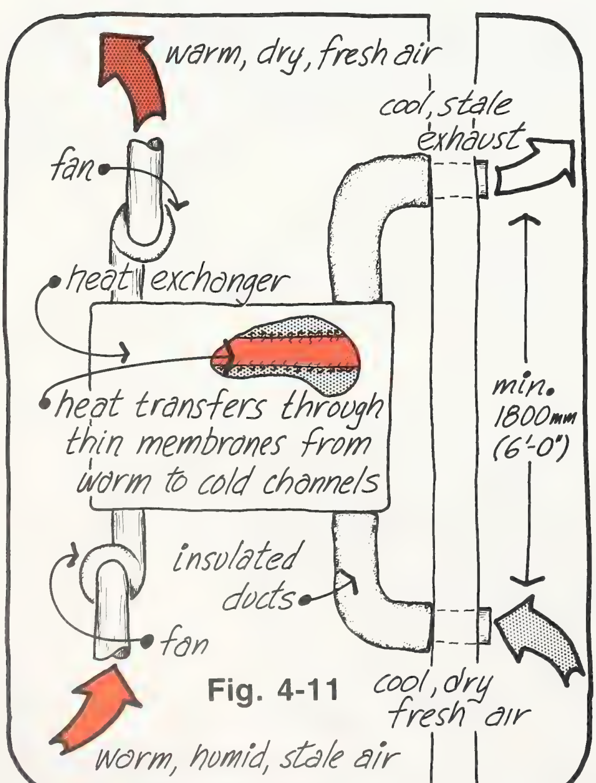


Fig. 4-11

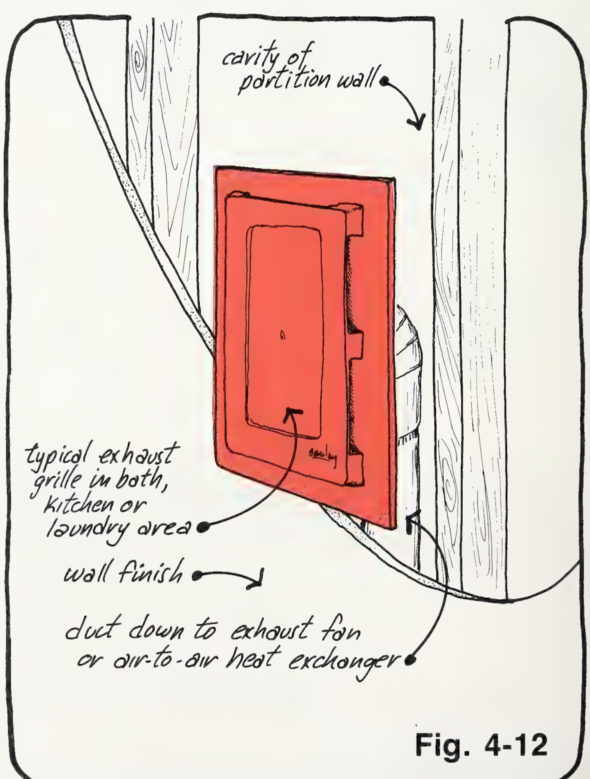


Fig. 4-12

concerned do-it-yourselfer during home construction. Added to which, more and more designers, contractors, and tradespeople are becoming knowledgeable about energy-efficient construction.

The well-sealed, energy-efficient home has very little air leakage and, as a result, may need a controlled ventilation system to keep air fresh and dry. Mechanical systems using intake and exhaust fans will allow the homeowner to control the rate of fresh air coming in. Incorporating an air-to-air heat exchanger into the mechanical ventilation system will prevent some of the excess heat loss that occurs from exhausting heated air.

NEW HOMES: HEATING CHOICES

OUTLINE

Constructing a home in an energy-efficient manner has a dramatic effect on the choice of heating fuel and on the type of heating system. High levels of insulation and a well-sealed air-vapor barrier mean that the heating system energy demand may only be one-quarter that of a comparably-sized, standard-built home.

This program provides information on heating-fuel options and heat-distribution systems. Advantages and disadvantages of fuel types, operating procedures for systems, and requirements for ventilation are described in detail. Properly selecting, operating, and maintaining your home heating system is an important part of ongoing energy efficiency.

A. Heating the Energy-Efficient House

1. Energy Requirements

As indicated in Table 1-1 (page 1), the total energy requirement for a standard home is about 225 GJ (210 million btu) per year. All of this energy, however, does *not* have to be purchased. Heat given off by appliances and lights, people, and pets can contribute up to 20 GJ—almost 10% of the total energy requirement.

Also shown in Table 1-1 is the typical demand of 55 GJ (52 million btu) for an energy-efficient home. The internal gains from appliances, lights, and occupants, of course, will still amount to 20 GJ. Thus, 205 GJ of energy must be purchased for the standard home, while only 35 GJ need be purchased for the energy-efficient home—*less than 20% as much.*

Obviously, a very small-sized heating system will be adequate for the **total heating load** of most energy-efficient homes. (Total heating loads are usually provided by the home designer, or can be calculated by heating contractors.) In fact, the heating system should be no more than 30% oversized. For example, if an energy-efficient home requires a heat source capable of providing 15 kW (50,000 btu), then a source no larger than 20 kW (65,000 btu) should be installed. This will be adequate to heat the home, even on the coldest winter nights.

2. Interior Temperature

An important part in the efficient operation of a heating system is the temperature maintained in the space. Heat loss is dependent on the temperature difference between inside and outside. The *lower* you keep the inside temperature, the *less* the rate of heat flow through the walls, floors, and ceilings. It is unreasonable to keep the temperature too low, but, during the morning and evening, an interior temperature of 18°C to 20°C (66°F to 70°F) should be comfortable.

At night, when everyone is in bed, and also during the day if no one is at home, the temperature can be lowered to 15°C (60°F). Up to 10% can be saved on a typical energy bill with such temperature setbacks. Thermostats can be manually setback for each period, or automatic setback units can be used to control the heating system (Figure 5-1).

3. Types of Fuels

A number of fuels are commonly used for home heating in North America. Table 5-1 lists some types, together with the quantities required to provide 1 GJ (948,000 btu) of useable heat. The figures given assume the fuels are being used in appliances with typical efficiencies (for example, gas furnaces at 65% efficiency, electrical resistance heating at 95% efficiency, etc.).

To calculate the lowest-cost energy source in your area, obtain local prices for each source. Multiply the quantities required to obtain 1 GJ, and the last column will show the cheapest alternative available.

Table 5-1 FUEL QUANTITIES REQUIRED FOR ONE GIGAJOULE OF USEABLE HEAT

Fuel Type	Quantity	Local Cost	Cost/GJ
Electricity	279,000 watts (279 kwh)	______/kwh	$ ______
Natural Gas	27 m^3 (1185 $ft.^3$)	______/mcf	$ ______
Fuel Oil	34 litres (7.5 gal.)	______/L	$ ______
Propane	53 l (11.6 gal.)	______/L	$ ______
Wood (birch)	97 kg (213 lb.)	______/kg	$ ______
Coal	83 kg (182 lb.)	______/kg	______

The cost of a fuel may not be the only factor you have to consider when making a fuel choice. There are a number of advantages and disadvantages to each fuel. Review them as follows, keeping in mind that the demand in an energy-efficient home is quite small.

a) Electricity

Since homes require an electrical utility hook-up for the operation of lights and appliances, using electricity as a heating fuel can be very convenient. Although the cost may be high compared to other fuel types, the small amount required to heat an energy-efficient home may still make electricity the best choice.

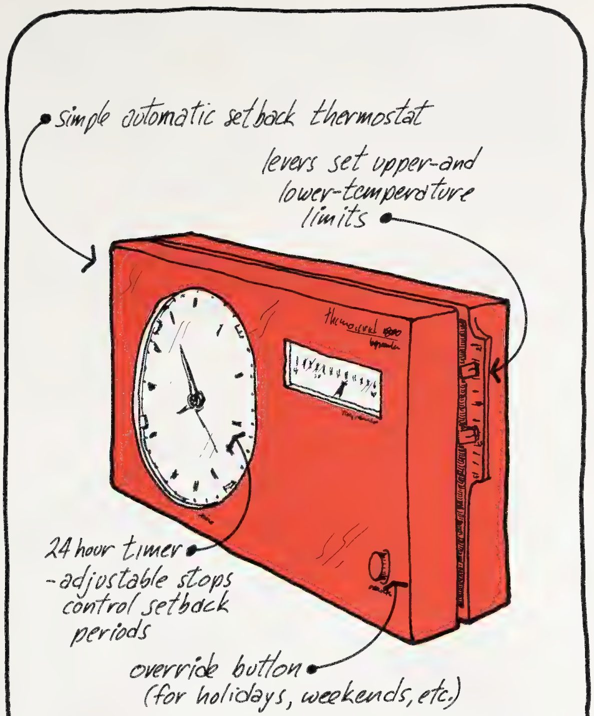


Fig. 5-1

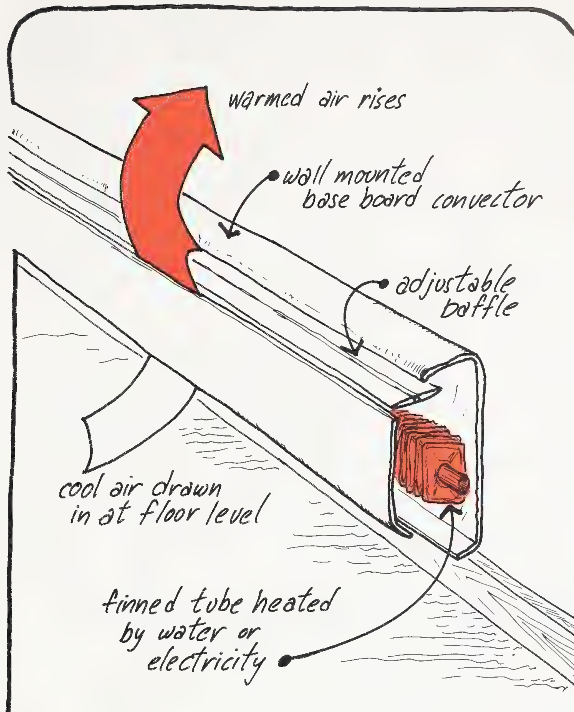


Fig. 5-2

A big advantage in using electricity for space and hot-water heating is the elimination of the need for a chimney—*a large source of air-leakage heat loss.*

There may be a considerable cost involved in hooking up to an electrical utility. Transmission lines are expensive to install over long distances. However, the only alternative is wind- or diesel-powered generators—often more expensive alternatives.

b) Natural Gas/Propane

Where available, natural gas is supplied through high-pressure underground lines and requires no storage or handling. Propane needs on-site storage in tanks under high pressure. The gas pressure in either case is lowered by way of a regulator valve where it enters the home. Gas-burning appliances contain safety devices to stop the flow of gas if the pilot light goes out or ignition is unsuccessful.

In areas where transmission lines exist, natural gas is often the most convenient and economical fuel to use. However, in locations far from transmission lines, the cost of piping gas to an individual residence may be quite expensive. Propane is a good alternative if gas is the desired fuel.

c) Fuel Oil

Although transmission lines exist is some areas, most fuel-oil installations operate from a storage tank in the building being heated. There is some inconvenience involved with fuels that must be stored on site—cost of tank, access for delivery, necessity of ordering supply, etc. And, in many areas, servicing may be difficult to obtain because of limited use.

Note that oil-burning appliances need regular maintenance to ensure operating efficiency.

d) Wood/Coal

The use of solid types of fuel necessitates provision for access and for large storage volume. There must be a ready means of moving fuel into the home and, for that matter, carrying out ashes. Wood- and coal-burning appliances need more attention than gas- or liquid fuel-burning types. Chimney maintenance is also a critical part of operation.

Using wood or coal does not restrict you to a radiant-heat source (e.g., a simple stove). Both forced-air and hot-water heating systems can be operated with wood- or coal-fired units. But these systems do need replenishing two or three times daily during the heating season. Wood and coal

can be expensive systems for heating if supplies are located far away. In addition, pollution can be a problem in densely populated urban areas.

4. Heat-Distribution Systems

There are two basic ways of distributing heat within a home. One method uses radiant heat sources placed throughout the house, while the second uses forced air to distribute heat from one central source. Different fuels and appliances can be used to provide the heat.

a) Radiant-Heating Systems

This type of heating involves a heat source located in a space that radiates heat to the air around it. The action of warmed air rising and cool air falling works to circulate the radiated heat throughout the space.

The radiant-heat source can take the form of individual room units (Figure 5-2), using electricity or hot water, units that have individual thermostats for temperature control. Hot-water systems rely on a single boiler, which can be fired with *any* type of fuel (Figure 1-6).

Other radiant-heat sources include individual space heaters, such as wood or coal stoves (Figure 5-3). (You must be careful to observe the manufacturer's recommended clearances from combustible surfaces when installing this type of unit.) To heat an entire home adequately, the design of the plan must be very open, or else heat will not distribute evenly to all the spaces being heated. Open grilles can be used to promote hot-air circulation (Figure 5-4).

Another source, although not a very efficient one, is a fireplace. Its poor efficiency can be improved by employing a unit that controls combustion with glass doors, fresh-air intakes with dampers, recirculating features, etc. (as shown in Figure 5-5). *Fireplace opening doors and dampers must be tight-fitting to control air-leakage heat losses when the unit is not in use.*

Radiant floor/ceiling heating (Figure 5-6) is another option, using either heated water or electrical resistance elements. These systems are difficult to design properly and create problems if breakages occur, but do provide a clean, even, hidden source of heat if installed correctly.

b) Forced-Air Heating Systems

A typical forced-air system is shown in Figure 1-7 on page 6. The furnace can be fired with any type of fuel, including electricity, and the system operates as shown in Figure 5-7. By designing the return-air ducting to draw air from near-ceiling level (Figure 5-8), passively heated air, plus heat from internal sources that stratifies near the top of the heated space, is drawn down into the system and distributed throughout the home.

Leaving the fan running constantly at a low speed aids the uniformity of heat distribution from passive or internal sources. (It runs at a higher speed only during actual furnace operation.)

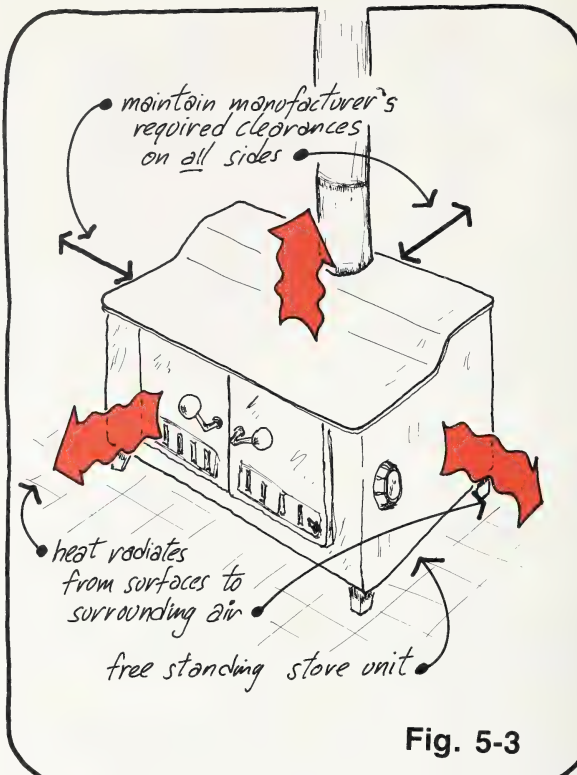


Fig. 5-3

It is vital to efficient operation that the furnace be properly sized. A unit that is too large will operate very inefficiently. After the blower ignites, the heat exchanger takes a few moments to warm up before the fan starts to blow air across it, picking up the heat. When the burner stops, the fan continues to run until the heat exchanger is cooled to near room temperature. An efficiently sized furnace will operate almost continuously in cold weather, while a larger furnace will cycle on and off easily, heating the space in short bursts of operation. However, a furnace is most inefficient at start-up and cool-down, thus *the fewer on/off cycles, the better.*

Heating-fuel conservation can be further enhanced by purchasing efficient heating units. There are gas-fired furnaces available with electronic ignition to eliminate the standing pilot light and also with automatic flue dampers to stop air-leakage heat loss up the chimney when

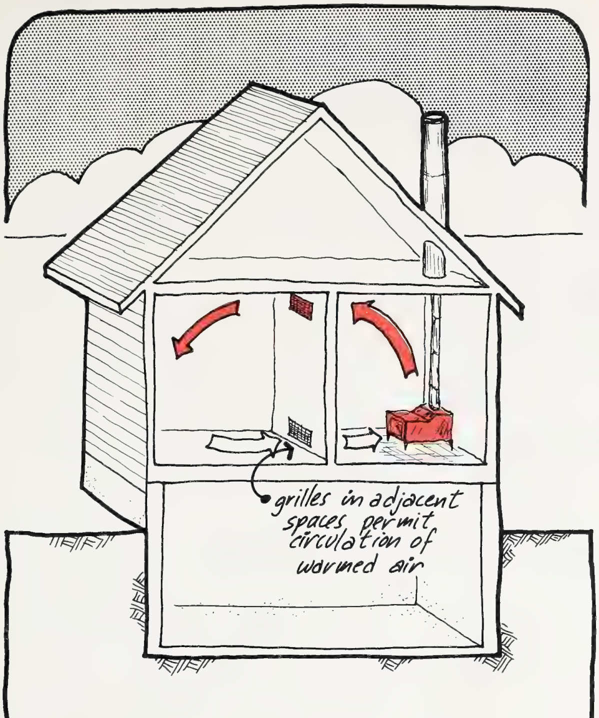


Fig. 5-4

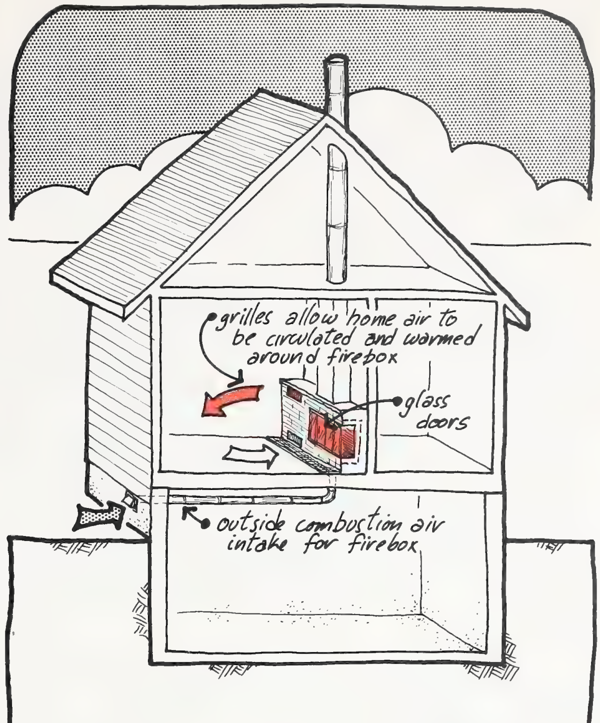


Fig. 5-5

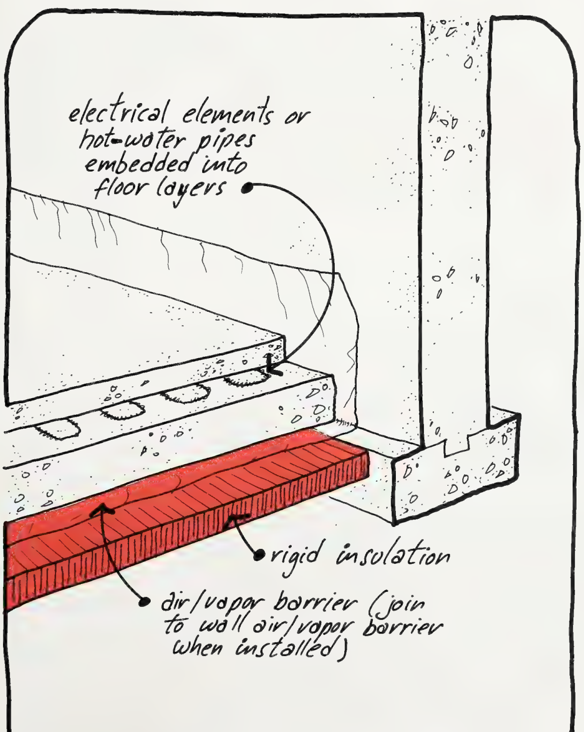


Fig. 5-6

the furnace is idle. Also available are high-efficiency furnaces (Figure 5-9) that condense the water vapor in the exhaust gases to release a large amount of heat (lost up the chimney in standard furnaces). The cooled exhaust gases vent through a small pipe in the joist space, and the condensed water vapor exits via a convenient floor drain.

5. Combustion Air

Fuel-burning appliances require air for combustion as well as proper chimney operation. Since energy-efficient homes tend to be well-sealed, *a separate inlet for combustion air is needed.* In fact, it will probably be a local building code requirement. Fresh air for the occupants is also necessary in well-sealed houses. Although improvements in fuel-burning appliances include electronic ignition, chimney dampers, and condensing exhaust heat exchangers, air is still needed during flame operation.

Isolating a fuel-burning appliance in a room with its own air supply (Figure 5-10) is one way of ensuring that heated air from the home is *not* used for combustion. Two inlets into such a space will ensure that there is adequate combustion air, as well as a supply of fresh air.

B. Ventilating the Energy-Efficient House

Fresh air for the occupants of a home is an important consideration. Although the object of an energy-efficient house is to make it as air-tight as possible, *the entire volume should be exchanged every three or four hours.* This prevents the build-up of humidity, odors, and pollutants that occurs in a totally sealed space.

1. Mechanical Ventilation

Mechanical fans can be installed to provide a controlled air-change rate. Humidity levels are the best indicators of a low ventilation rate. (As the humidity rises, condensation occurs on such cool surfaces as window glazing.) If the mechanical-ventilation system is controlled by a humidistat, then a comfortable level of humidity can be set, above which the exhaust fan will automatically remove air (replacing humid air with dry, outside air). Override-type switches can be installed in bathrooms and laundry areas to provide short-term high-velocity, air-exchange rates.

The separate kitchen, bathroom, and utility area fans that exhaust through the ceilings of standard homes create many hard-to-seal breaks in the air-vapor barrier. In an energy-efficient

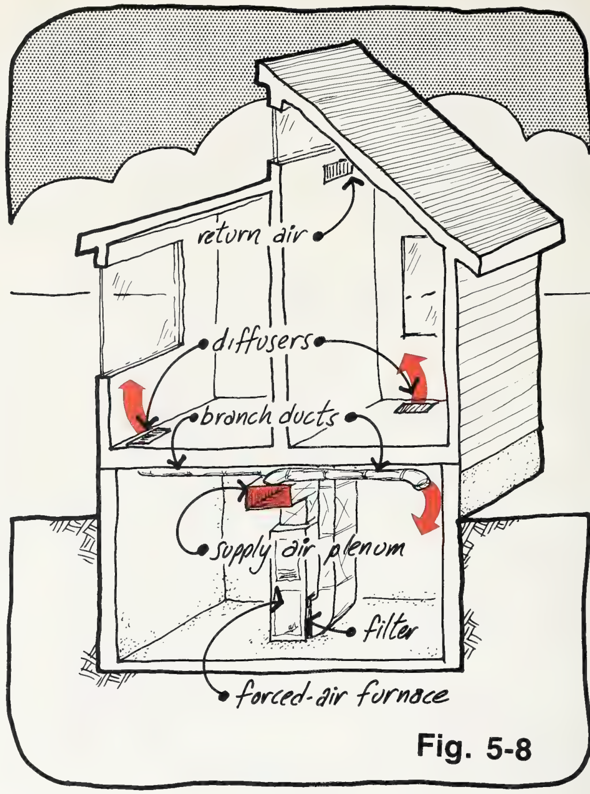


Fig. 5-8

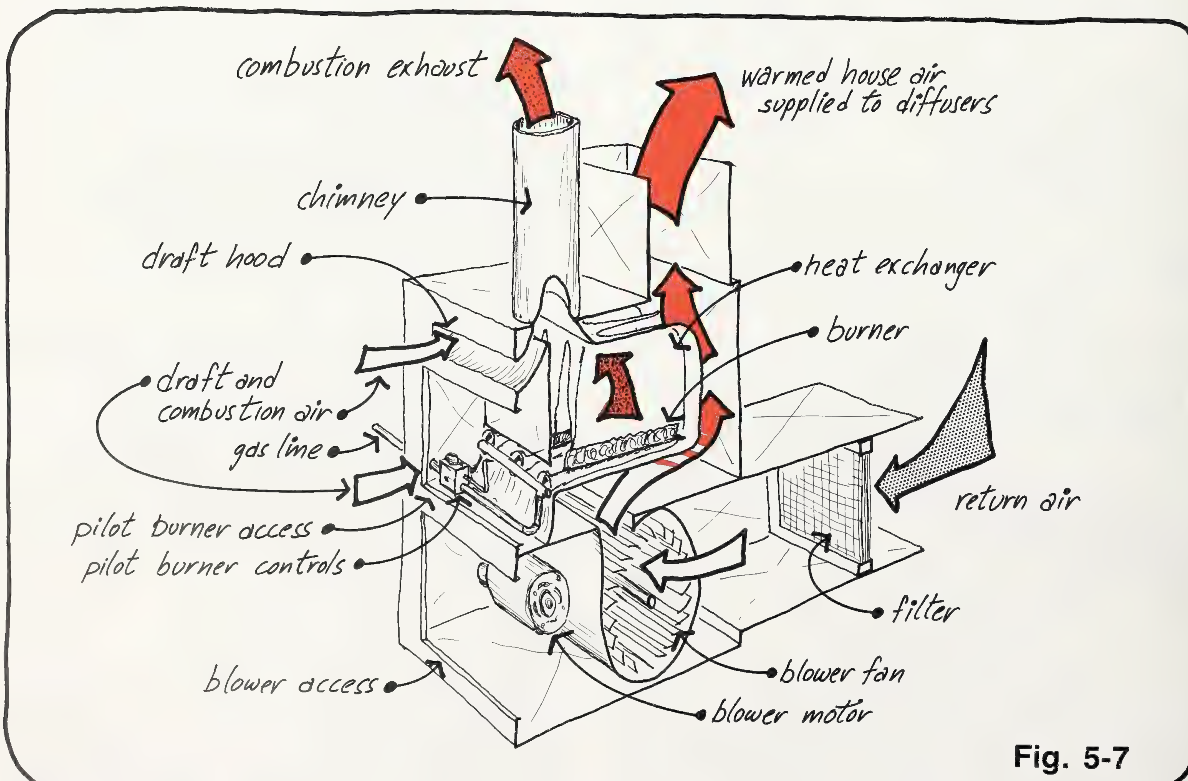


Fig. 5-7

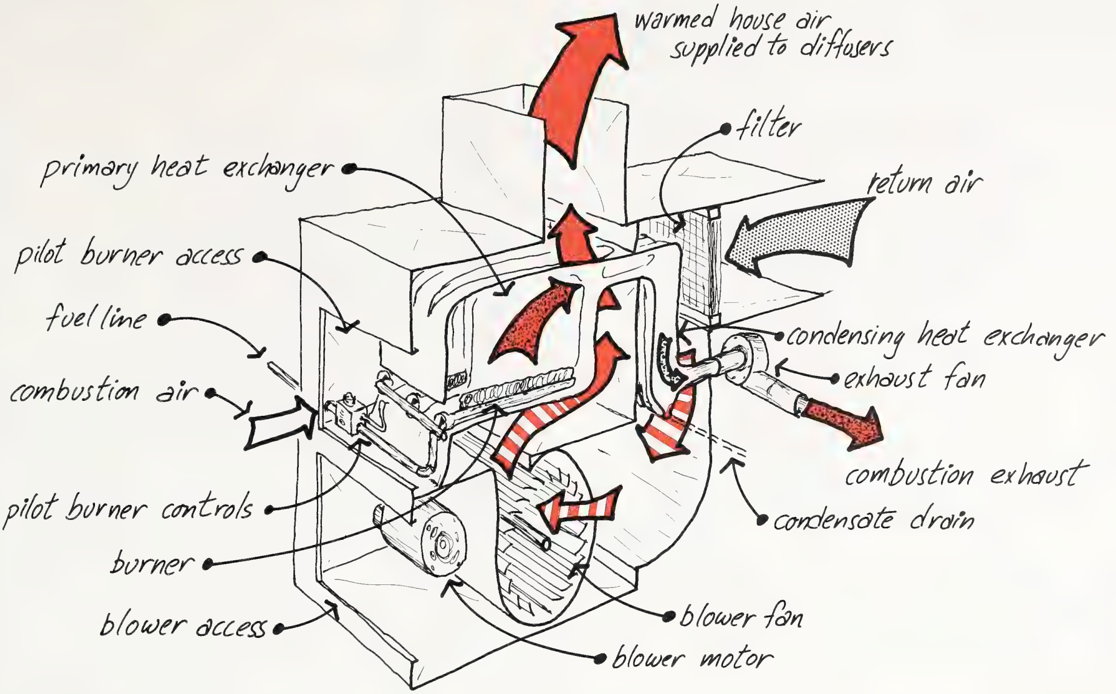


Fig. 5-9

home, these exhaust ducts are fed down interior partition walls (Figure 5-11) and joined in a main exhaust duct that exits out the joist space. This means that only *one* exhaust vent is required, and one large fan can provide enough ventilation for the whole house. An *intake* vent (spaced at least 1800mm or 6' from the exhaust vent) and a fan will feed fresh air into the home to replace the exhausted volume.

2. Air-to-Air Heat Exchanger

Although mechanical ventilation may be required to keep the air dry and fresh, a large amount of heat is lost when air is exhausted. By installing an air-to-air heat exchanger in the exhaust/intake lines of a ventilation system, much of this heat can be recaptured.

A simple schematic of an air-to-air exchange operation is shown in Figure 5-12. One fan is used to draw warm, humid, stale air from the home and pass it through the exchanger, where it gives up most of its heat before being exhausted. Another fan draws in cool, dry, fresh air to replace the air exhausted. This fresh air picks up most of the heat from the exhaust air in the exchanger. Air-to-air heat exchangers are made of many channels. The exhausting air travels in one direction in every second channel, and the incoming air travels in the other direction in alternate channels. As the air flows pass each other, the warmer streams transfer heat by conduction to the colder, incoming streams.

Logical areas to locate exhaust grilles (Figure 5-13) are in bathrooms, the laundry area, and the kitchen. Clothes dryers and kitchen range hoods should *not* be directly vented into an air-to-air heat exchanger. Lint and grease will quickly plug up the small air channels. Fresh, warmed air from the exchanger can be distributed in the home by one of the methods illustrated in Figures 4-9 and 4-10, depending on the type of heating system.

C. Cooling the Energy-Efficient House

High levels of insulation and a well-sealed air-vapor barrier create an energy-efficient home that *will stay cooler in summer,* as well as warmer in winter. Utilizing cool evening breezes for night-time cooling, air conditioning should not be required in most regions: the high insulation levels will lower the heating effect of the sun during the day. However, you should take advantage of the site design to promote natural cooling (Figure 5-14).

Design features should include window placement for good cross-ventilation (Figure 5-15)

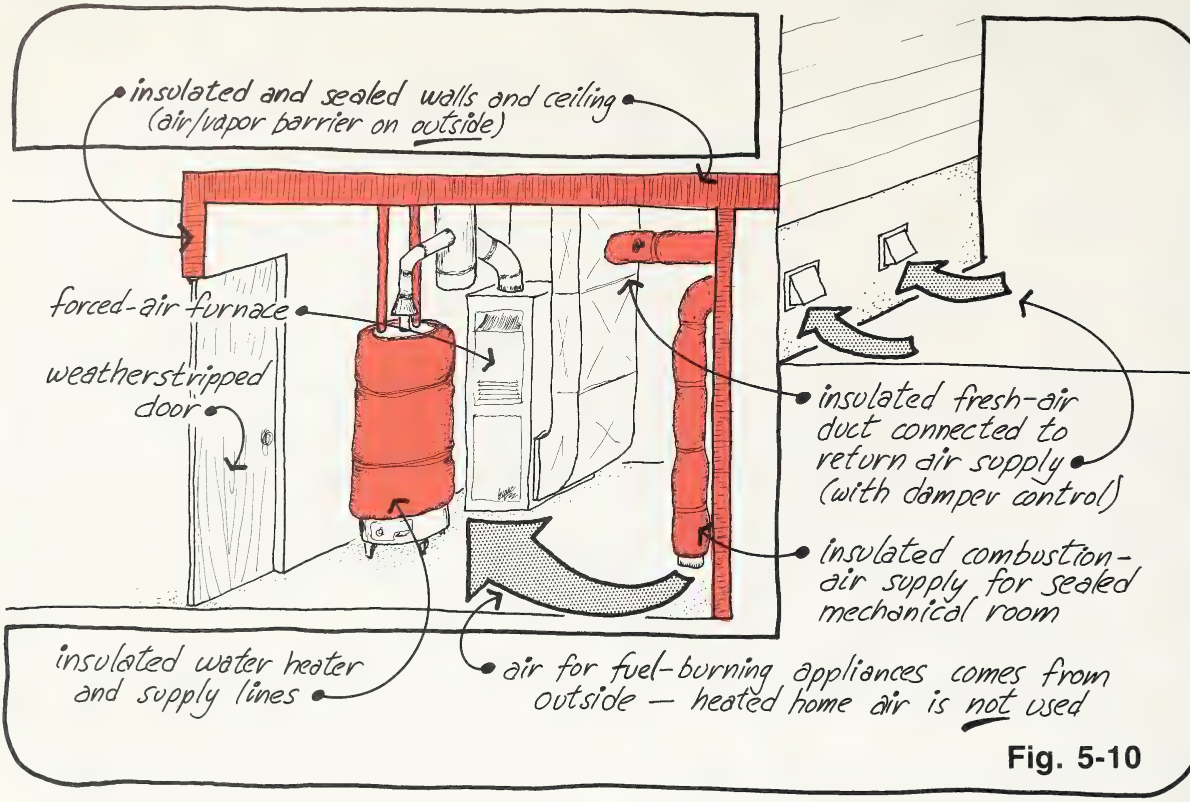


Fig. 5-10

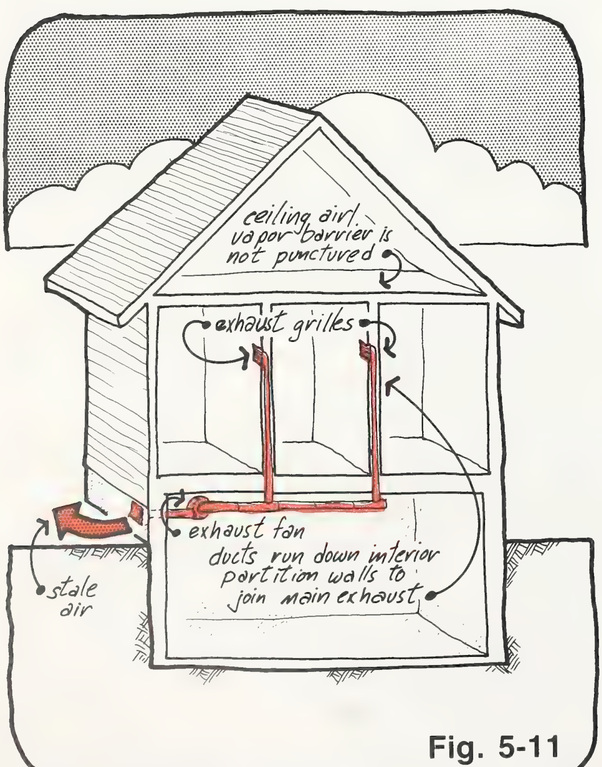


Fig. 5-11

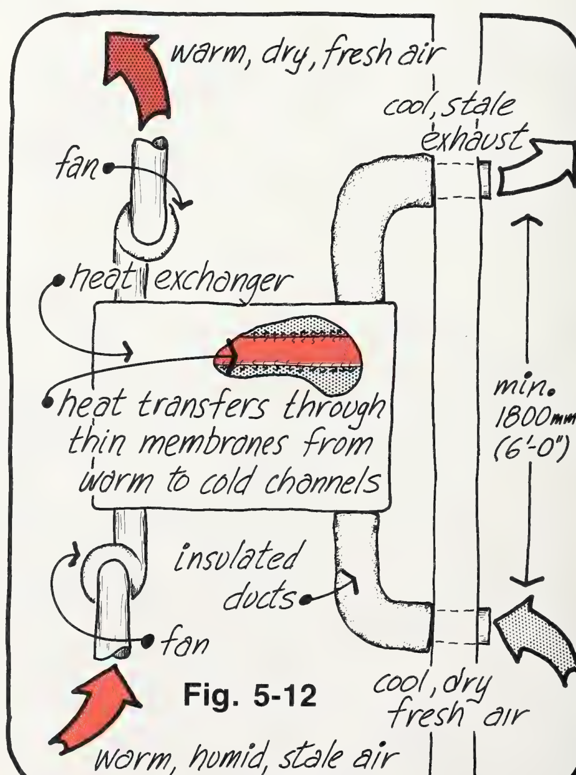


Fig. 5-12

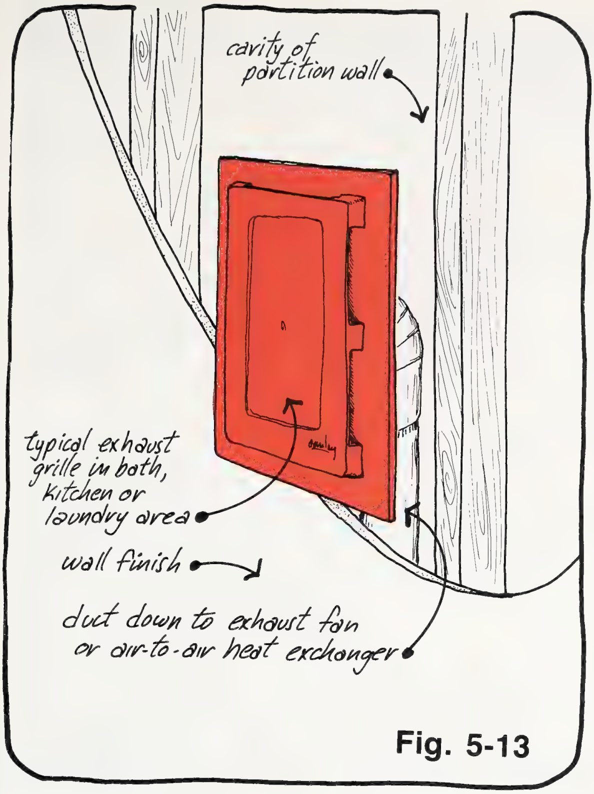


Fig. 5-13

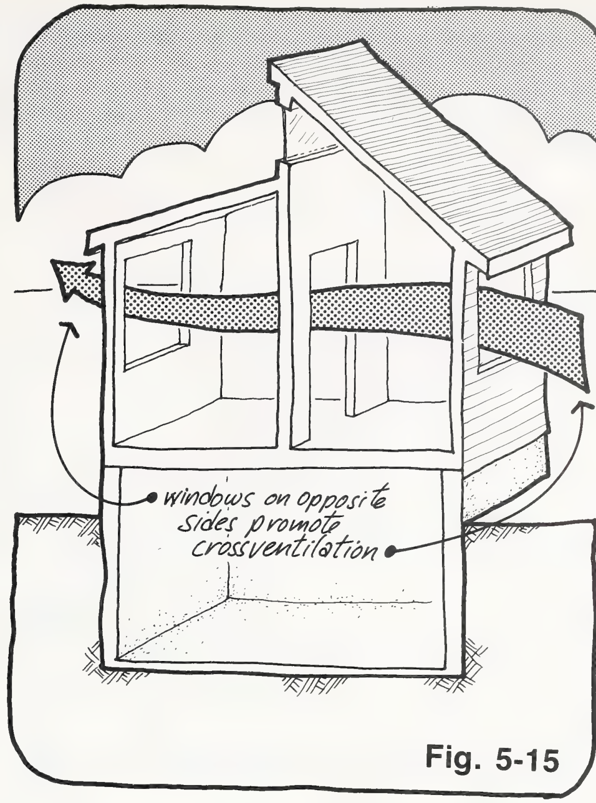


Fig. 5-15

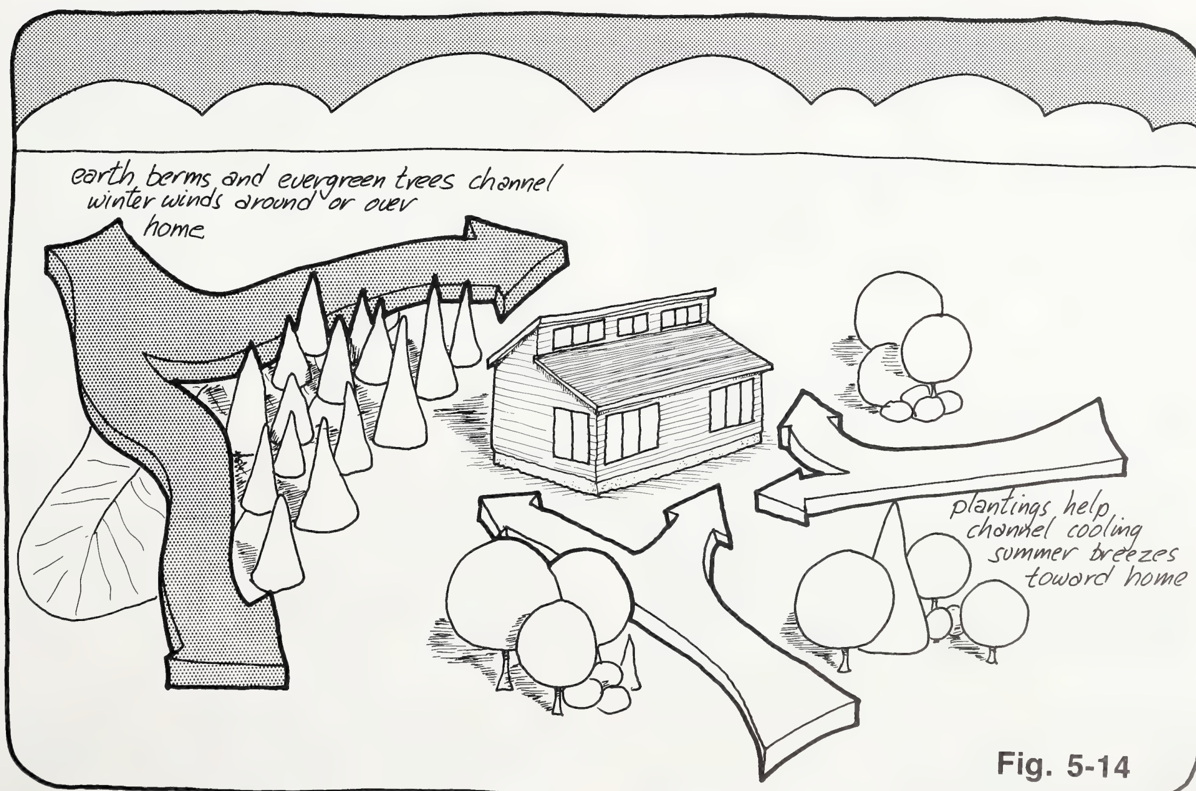


Fig. 5-14

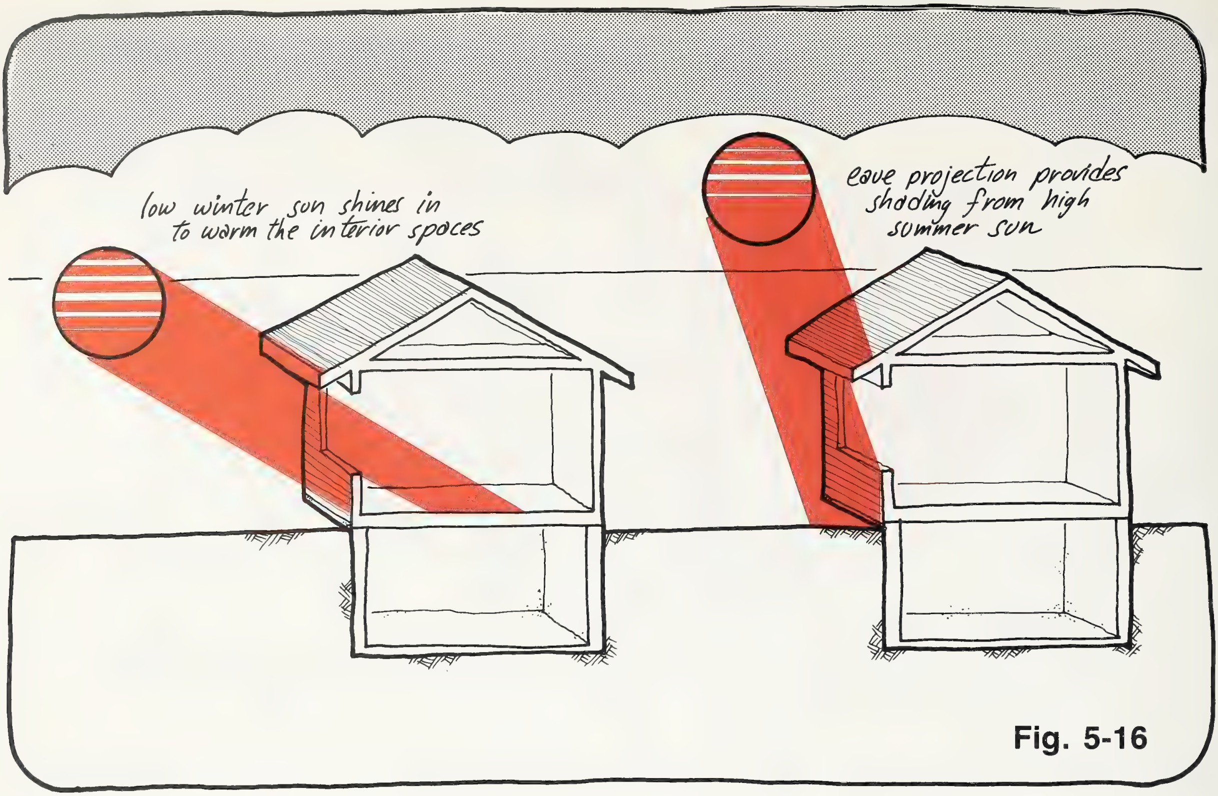


Fig. 5-16

and eaves to shade south-facing windows (Figure 5-16). Minimizing window space on the east and west sides will lessen the effects of passive solar gain since, in northern latitudes, the sun is always low, even in summer. Plant trees to provide natural shading during the hottest part of the day. Deciduous trees work well in cool climate zones. The leaves give excellent summer shading, but drop off in the fall and allow solar benefits in winter months.

Summary

The options available for heating fuels and systems are quite extensive. Since an energy-efficient home requires such a small energy supply, *cost may not be the determining factor in choosing a fuel and a heating system.* Availability in your area or nearness to the home site may be the matters to consider. Take into account, too, the convenience of fuel use—wood requires a lot of effort, fuel oil prices are rising, storage of coal can be problem, etc.

The importance of combustion air and fresh air cannot be overlooked in the operation of the heating system. These aspects must be designed into the structure so that fuel-burning appliances can operate properly and fresh air is distributed throughout the home. Installing the most efficient heating and ventilating systems will provide long-term operating benefits in matters of fuel usage and of operation and maintenance.

NEW HOMES: LETTING THE SUN SHINE IN

OUTLINE

The preceding programs in the *Energy-Efficient Housing* series have dealt with construction techniques aimed at lowering home energy demands. However, in addition to high levels of insulation and a carefully-sealed air-vapor barrier, natural forces can be utilized to decrease home energy requirements. Evening breezes in the summer can be used to provide natural cooling, and the winter sun can supply some of the space heating required.

This program explains how design and siting can take advantage of those forces. The result is a more comfortable home and surrounding environment, as well as lower fuel bills. The effect just of the sun on the site can go a long way toward lowering the resource requirements of an energy-efficient house.

A. Solar Energy

An enormous amount of power arrives daily on our planet in the form of radiant energy. How can it be utilized in the typical home? There are two different methods of capturing solar energy: *active* and *passive.*

Any surface exposed to sunlight will have an increase in temperature as it absorbs radiant solar energy. This heat may be stored in the material or conducted to adjacent materials. It may also be carried away by air or liquid flowing past (convection), or the heat may be radiated back toward the cooler sky.

A clear material like glass makes the collection of solar energy possible. Once sunlight passes through a window, for example, it is transformed to heat energy by the objects it strikes inside. *This heat energy is not radiated back through the window as readily as the light energy that enters* (Figure 6-1). This phenomenon is known as the "greenhouse effect."

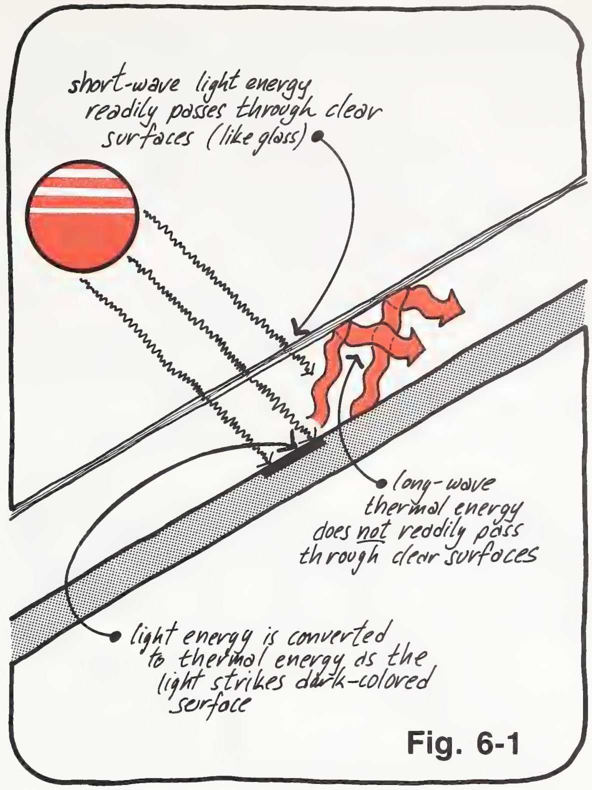


Fig. 6-1

The basic object of any home solar-energy system is to trap solar radiation and convert it to heat energy. This energy can then be used to supplement conventional home-heating fuels. It is very important that solar access to the site be maintained during the heating season. Make sure there are no obstacles to block sunlight—and that there will not be any in the future.

1. Active Solar-Energy Systems

Active solar-energy systems have now been developed, tested, and utilized (Figure 6-2). Most residential installations consist of: a *collector*, which converts solar radiation to thermal energy; a *transmission system* using either air or water to move the heat; a *storage mass* to hold the heat for later use; and a *distribution network* to circulate the captured heat throughout the space when required. Fans or pumps are needed to move the energy through the transmission or distribution systems—either from the collector to storage or from storage to the space being heated. Energy is needed to run those fans or pumps, hence the term "active" solar energy.

The many complex parts and controls required to operate this system make it *a very expensive installation.* Energy is needed for operation, the maintenance requirement is considerable and, as with any mechanical system, the components have a limited life span. The necessity that the transmission network—air ducts or water pipes—run through the building envelope means difficulties in maintaining a well-sealed air-vapor barrier. In cool climate areas of North America, *active solar-energy systems for residential heating rarely gather enough energy to justify their high installation expenses.*

2. Passive Solar-Energy Systems

As illustrated in Figure 6-3, passive solar-energy systems rely on parts of the building design and

construction for direct solar heating. The collector (simply a south-facing window) captures direct, diffuse, or reflected solar radiation, which is stored in a mass (the floors and walls or objects in a space), to be distributed by radiation later as the space cools down. In their simplest form, these systems have little control over temperature. Since the systems are an integral part of the building design, little or no cost is involved in their incorporation.

Passive heat collection can contribute 5-10% of the total heating load required in a conventional type of home. With more consideration to proper home siting, internal layout, window orientation, insulation values and airtightness, this total contribution can be greatly increased.

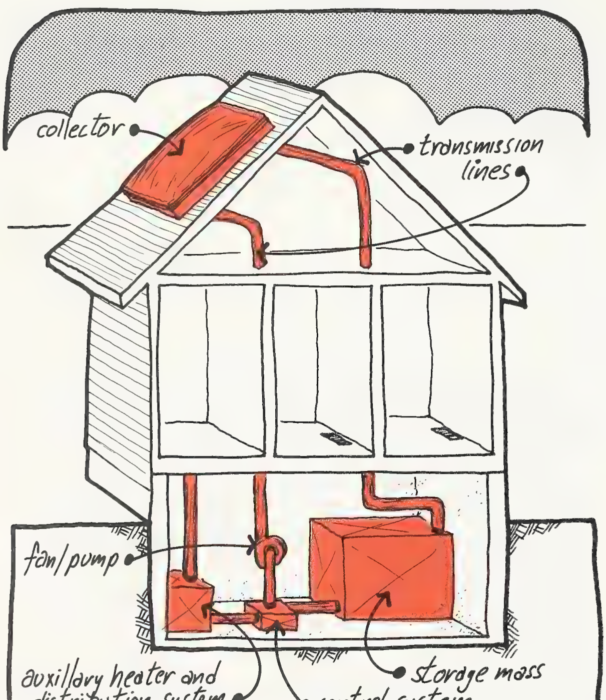


Fig. 6-2

B. Understanding Passive Solar Energy

Since energy-efficient homes have such a low demand for heating energy, passively collected solar energy can contribute significantly. Care must be taken, however, to prevent excess heat loss through windows at night or the benefits of passive collection are soon lost. Conversely, for most of the spring and summer, the design of a passive solar home must be such as to prevent *overheating*—letting in too much solar energy.

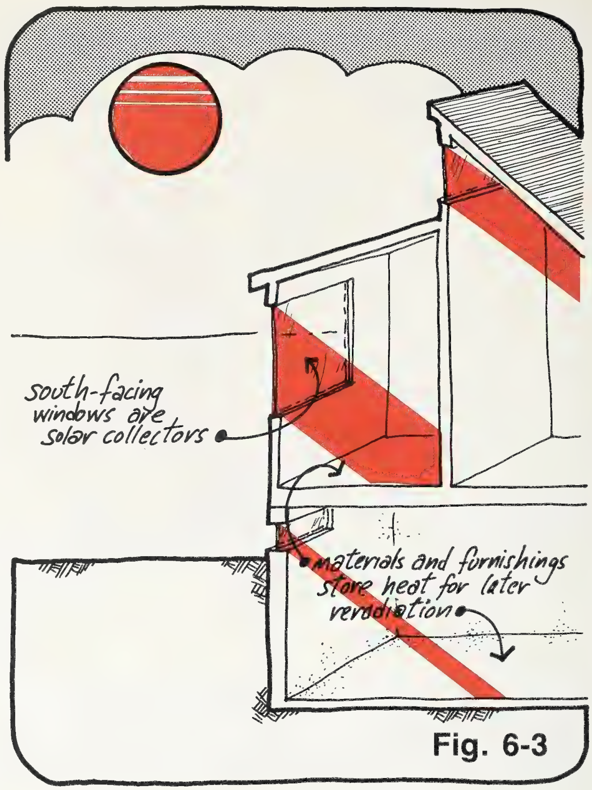


Fig. 6-3

1. Collecting Passive Solar Energy

The two basic elements of passive systems are *south-facing windows* and *thermal mass.* The energy can be captured either directly or indirectly. However, first, it is important to ensure that south-facing glass in solar homes has unobstructed exposure to sunlight during the heating season. This glass can be oriented up to 30° west or east of true south and still maintain its ability to capture most of the solar energy available (Figure 6-4).

a) Direct-Gain Systems

Any room with a south-facing window can be a direct-gain space. Orienting most of the windows south on a home will make it a direct-gain passive solar structure. Since north-facing windows are major sources of heat loss, clerestory windows (Figure 6-5) can be designed into a structure to increase the amount of south-facing glass, allow penetration of solar energy to the north side, and let natural light deep into the home. *However, only the equivalent of 6% to 8% of the total floor area of the house can be incorporated as south-facing glass or serious overheating is liable to occur.* Thus, if you have a 110m² home on a full basement (giving a total floor space of 220m² or 2400 ft²), the amount of

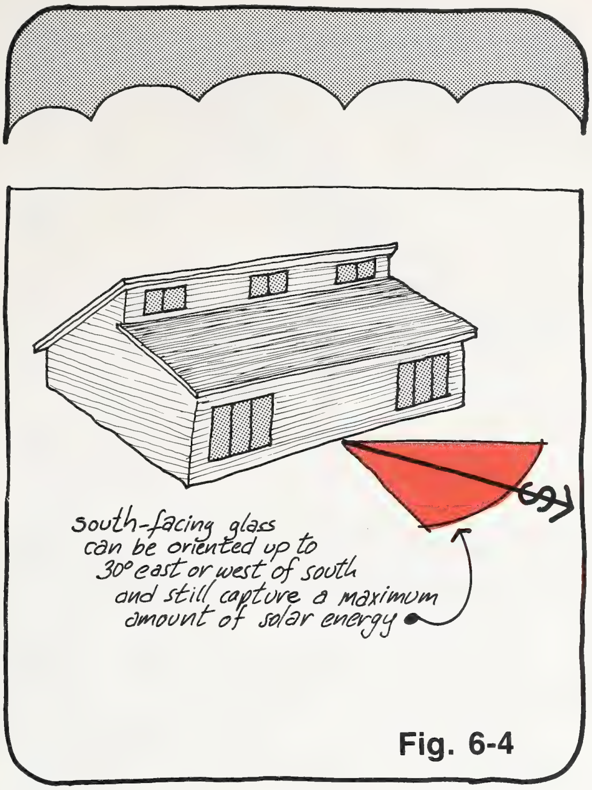


Fig. 6-4

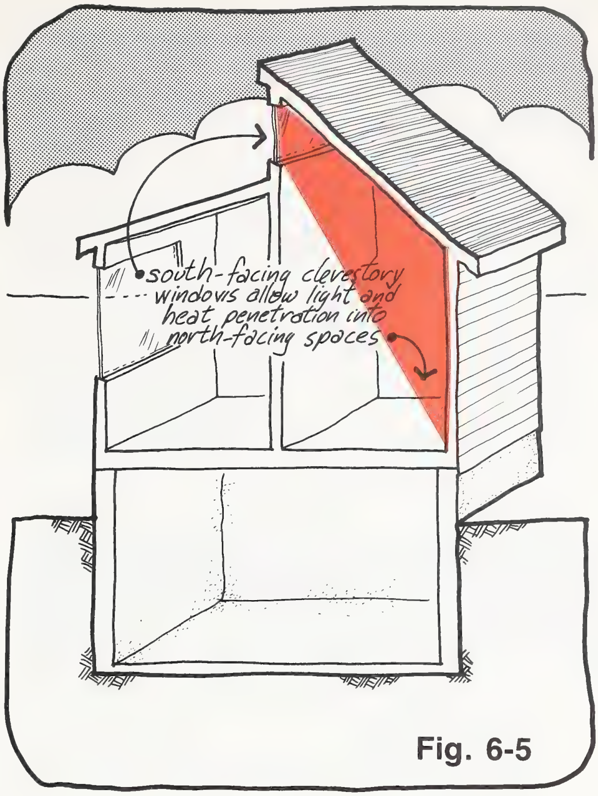


Fig. 6-5

south-facing glass should be, at most, only 8% of the total, i.e., 18m² (190 ft²). Most homes contain enough thermal mass in the form of building materials and furniture to absorb the energy coming in through this area of glazing.

If the window area does exceed the percentage noted, further thermal mass should be added to absorb the excess solar energy. This mass can be in the form of masonry feature walls, planters, a fireplace, or some type of water storage (Figure 6-6). As a general rule, for each square metre of south-facing glass in a space over the 8% maximum, you have to add 5m² of masonry 100mm (4") thick—a ratio of 1:5. Since mass absorbs and releases heat slowly, wide temperature fluctuations occur in direct-gain spaces—of the order of 5°C (10°F). Problems with direct-gain solar homes include glare, sun-faded fabrics, and heat loss through large windows at night.

b) Indirect-Gain Systems

Indirect-gain spaces allow better control and use of passive solar heating. In this type of system, as shown in Figure 6-7, sunlight strikes a thermal mass *between* it and the space or building to be heated. With this system, large areas of glass can be used. As a general rule, there must be one square metre of glass for every square metre of area to be heated (a 1:1 ratio). The thermal mass must be 300mm to 400mm thick (12" to 16") if masonry, or at least 200mm thick (8") if water. This type of passive solar collection works well if there is good solar access and a view you don't mind blocking with the mass walls. However, insulation of the windows at night is important to prevent heat loss from the mass.

c) Attached Sunspaces

Attached sunspaces are combined direct- and indirect-gain spaces in homes. They are directly heated by the sun but provide an *indirect means* of heating the space to which they are attached. These types of spaces usually have lots of glass area and are especially subject to overheating if both the roof and walls are glazed. *It is therefore important that the space be well-ventilated to control heat build-up* (as in Figure 6-8). Overheating can occur during any season, even on a sunny winter day. One drawback is that severe overheating and damage may take place if no one is present to operate shading or ventilating devices as needed.

To help heat the home, mass storage and some method of transferring the heat from the attached sunspace to the living space are required. This can simply be a wall between the

two areas (Figure 6-7), or a rock-storage, air-distribution system as shown in Figure 6-9. But such sophisticated storage systems require complicated damper, fan, and thermostatic control functions and start to become more and more like active solar systems.

A simple attached sunspace can be a useful heat-collection space. It should be able to withstand large temperature variations. It should be an area easily isolated and not operated during the coldest winter months. Using the space as a greenhouse is acceptable some of the time, but most plants cannot stand large temperature variations, and much energy will have to be pumped into the area to keep plants alive and well all year round. Further, light levels during the winter months may be too low for good plant growth.

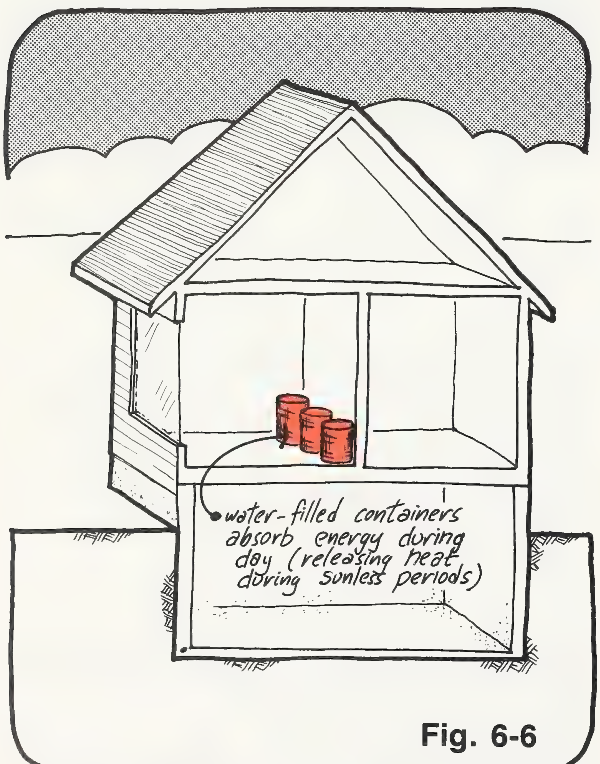


Fig. 6-6

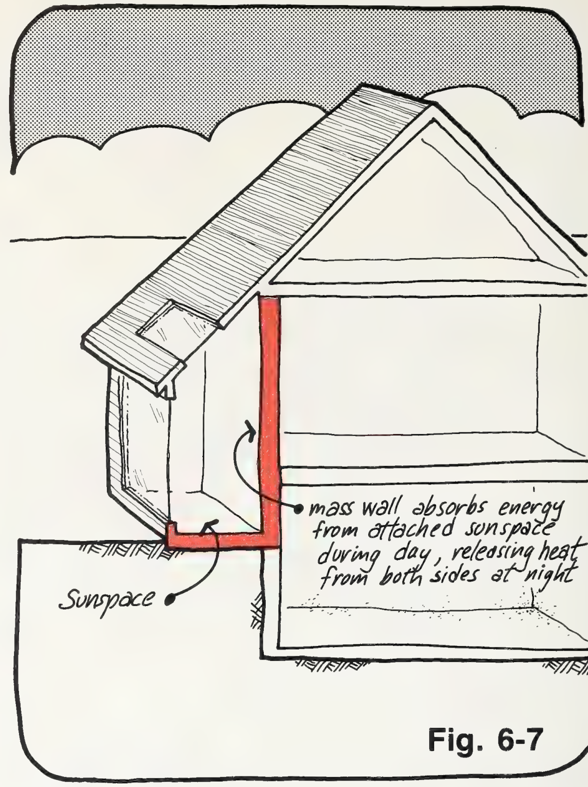


Fig. 6-7

Fig. 6-8

2. Using Passively Collected Solar Energy

Most of the solar energy absorbed as heat energy by the objects in a space simply re-radiates back into the space as the air temperature cools in the evening. Even specifically-designed, mass-storage devices such as brick walls or water containers give up most of their stored heat in this way. A forced-air, heat-distribution system, *with the return air intake placed near the ceiling level* (Figure 6-10),

will distribute the passively collected and re-radiated heat through the total home. More sophisticated heat-collection and distribution systems can be incorporated (as in Figure 6-9) but, again, may lend themselves to unnecessarily complicated operation and high maintenance costs. The simplest distribution systems—radiation and natural air convection—will cause the least problems.

3. Preventing Overheating

Overheating may be the largest single drawback to passive solar home design. Yet it is also the easiest problem to correct *if you take it into account at the design stage.* There are a number of external and internal factors that should be considered when designing a passive energy-efficient home.

a) Thermal Mass

As shown in Figures 6-6 and 6-7, thermal mass is used to soak up radiant energy and prevent overheating. However, it may not always be feasible to place that mass where the sun can shine directly on it. The forced-air heating system or a separate fan can be used to move the passively heated air to water- or rock-storage volumes remote from the collection area. A thermostat in the sunspace can activate a blower fan to remove excess heat and place it in storage. Similarly, a thermostat in the storage volume can activate the system to remove heat from it into the space as the temperature cools. Heat from the storage mass can simply radiate to surrounding areas as well (Figure 6-11).

Types of thermal mass include water, concrete, brick, rock, and eutectic salts. In addition, materials like wood, floor coverings, and wallboard, plus the furniture in a home, add to the mass.

Water is the most economical and efficient mass material but creates containment problems. Brick features are a good way of combining functionality and use—in walls, planters, or in fireplace and wood stove enclosures. Many homes are built on concrete basements. By insulating them *on the exterior,* that large mass will be included within the insulated envelope of the home. Rock storages are specifically designed and contained volumes. Heat can be transferred to them by blowing the warmed air through, and fist-sized rocks create the best storage in terms of mass and gaps for air to travel through. Eutectic salts are phase-change materials that have the ability to store great amounts of heat. As warm air is blown over the containers of salts (usually about 4 litres—a

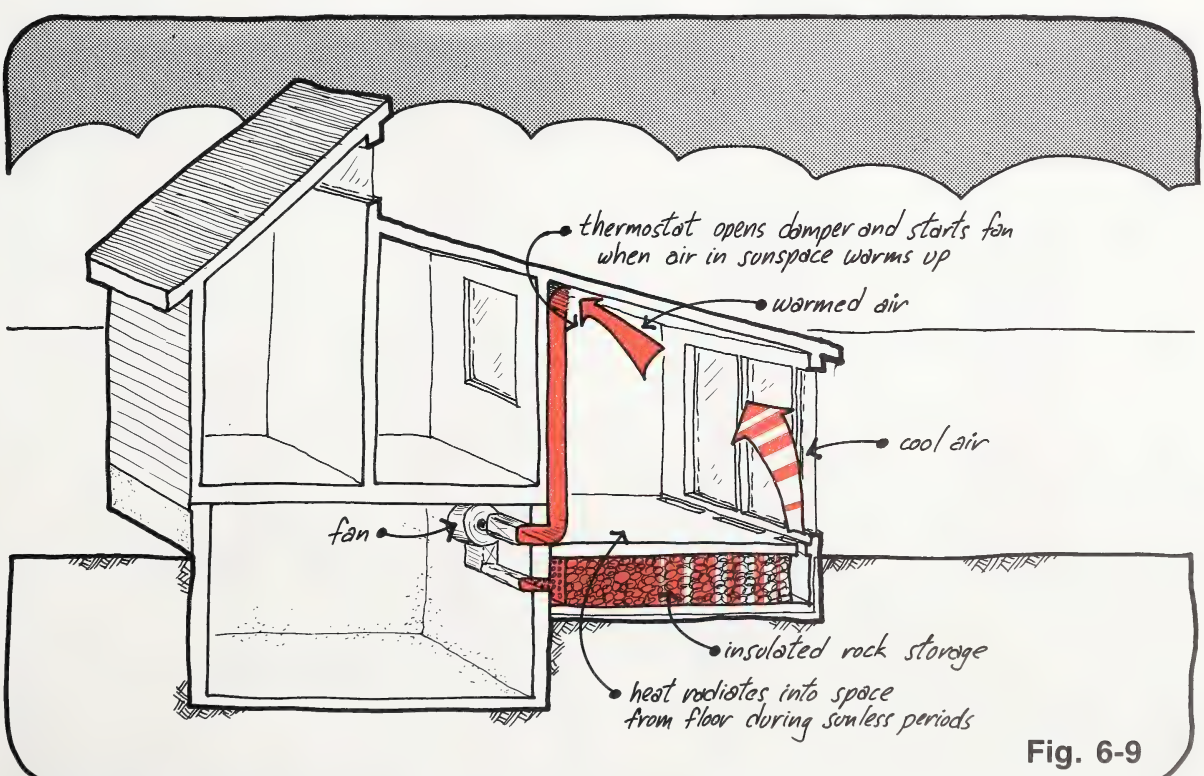


Fig. 6-9

gallon—in volume), the salts turn to liquid, absorbing heat. When the containers cool, the salts return to the solid state, releasing a great amount of heat as they change phase.

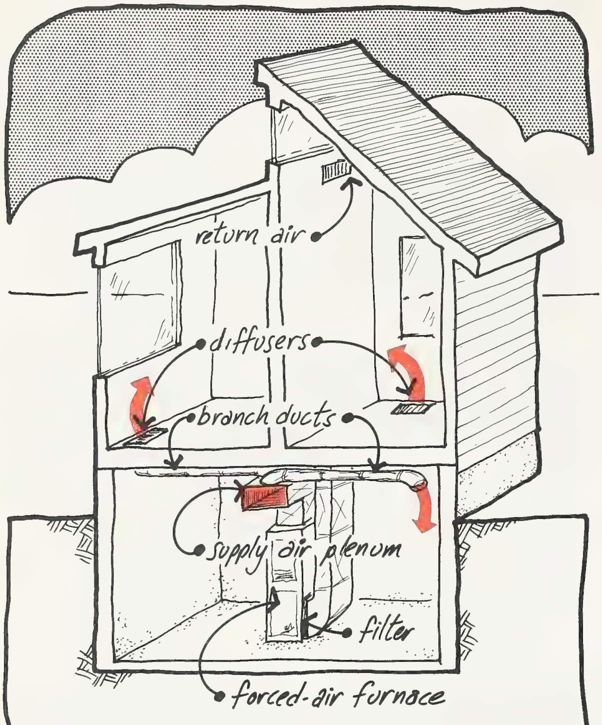


Fig. 6-10

b) Shading

Deciduous trees provide excellent shade in summer months to help prevent overheating. Since their leaves drop off in the fall, sunlight can reach the structure and enter through south-facing windows during the heating season. Overhangs can be designed to shade windows in summer and let light in during the winter months. The actual length of the overhang will, of course, depend on the latitude at which you live.

Other shading devices such as awnings or adjustable louvres (Figure 6-12) can also be used for controlling overheating. *Any shading device* should be on the outside. A shading device on the inside will not work as well since solar energy has already penetrated into the space by the time it strikes the shade. Adjustable shading devices work best since they can be opened and closed as necessary, regardless of the time of year. There are often sunny winter days when an energy-efficient house will overheat, and it is definitely an asset to be able to shade the windows on such days.

c) Ventilation

Adequate ventilation is another method of controlling overheating. Although energy-efficient homes stay cooler in summer because of high insulation levels and a well-sealed air-vapor barrier, natural ventilation should be provided with opening windows or screened doors. In multi-level homes, windows that open on different levels will promote natural ventilation. Warm air rising will exit at upper-level windows, drawing cool air in at lower level openings. Openable windows on different sides of one-level homes promote cross-ventilation.

There are times when ventilation is required in winter, too. The low sun angle on sunny winter days may cause short overheating periods in well-insulated homes with lots of south-facing glass. Opening a window or two for a short period will cool down the structure. Homes with clerestory windows (Figure 6-5) or roof windows like skylights, will have good natural ventilation if one or two of the units can be opened.

4. Window Insulation

Although windows are great passive solar-collection devices, at night they become uninsulated "holes" in your home. Double-glazed windows have an RSI-value of 0.30 (R 1.8),

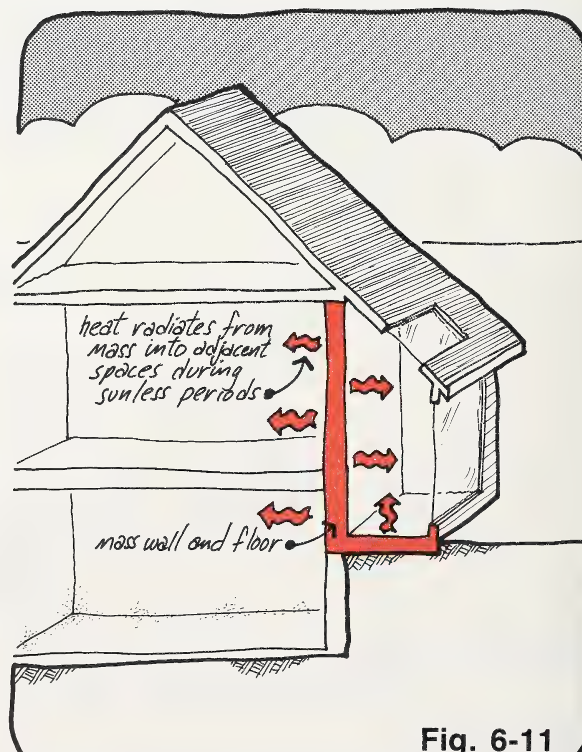


Fig. 6-11

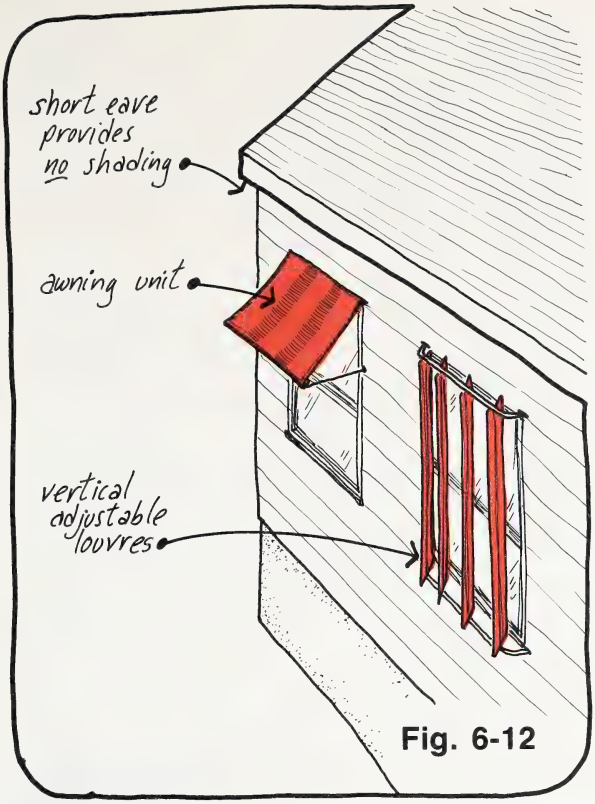


Fig. 6-12

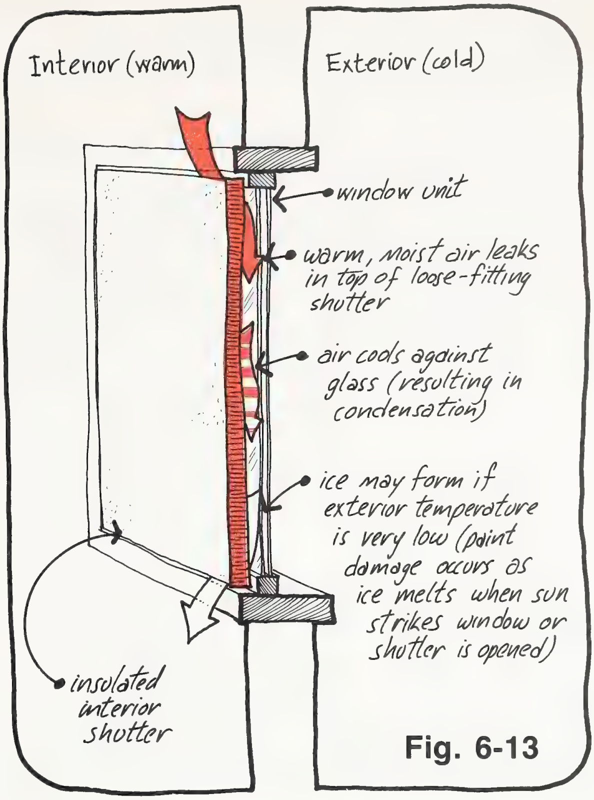


Fig. 6-13

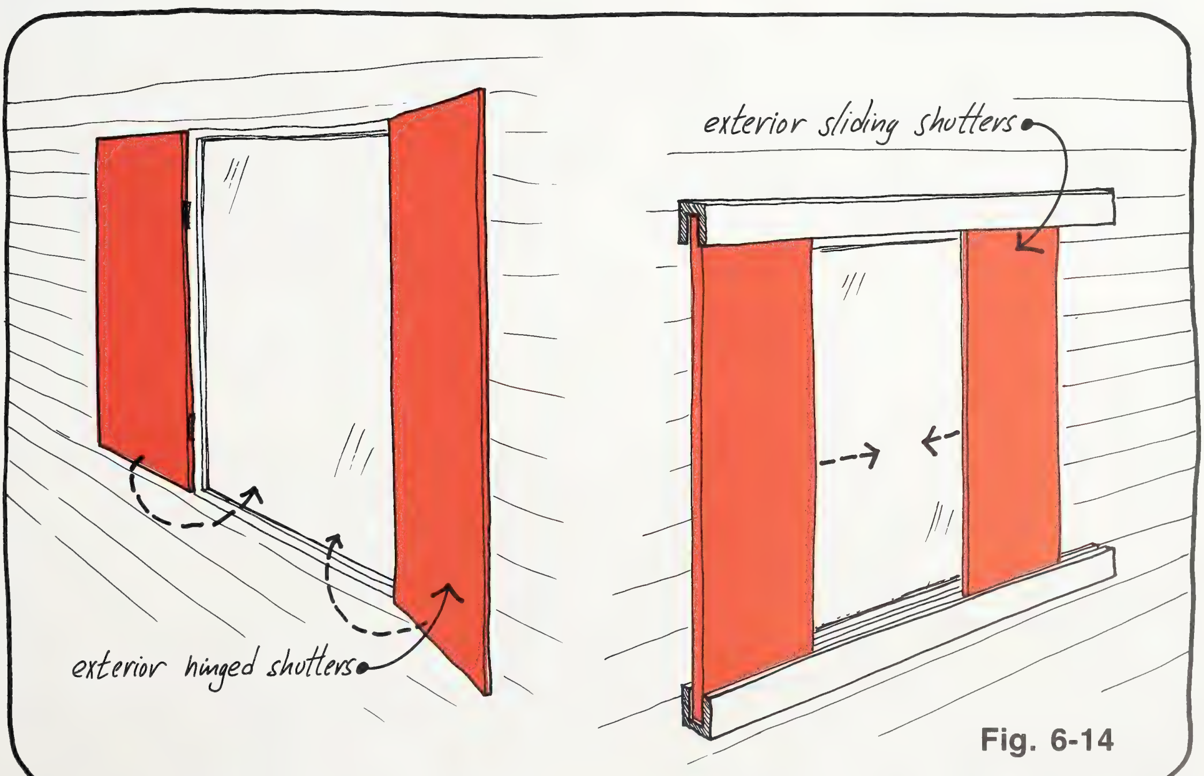


Fig. 6-14

which is less than one-tenth the insulation value of a typical wall in an energy-efficient home. Thus, the air space between layers of glass must be at least 12mm (1/2").

Windows rely on the insulative properties of air for their resistance value. Adding a third layer of glass to create a triple-glazed unit gives an insulation value of RSI 0.46 (R 2.7)—50% better, but still far below the value in a wall or ceiling. *More layers become expensive as well as cutting down on the solar energy allowed through* (each pane decreases light transmission by about 10%).

Moveable-window insulation is a covering that is applied to windows to control heat loss. It comes in many forms, as will be discussed and illustrated. You should choose a system that is convenient to use, one whose operation does not become a chore. Although expensive, many moveable-window systems eliminate the need for conventional drapery.

Moveable-window insulation can reduce heat loss through glass during the night or sunless periods. It can also function as a window cover, taking the place of a drape, and will make interior spaces more comfortable in cold weather. But, *to be cost effective, this type of insulation must be used consistently throughout the heating season.*

a) Interior-Window Insulation

Most forms of commercially available window insulation are mounted on the interior. However, any insulation mounted on the inside must fit very tightly all around the perimeter to prevent air leakage. As shown in Figure 6-13, if warm moist air can leak past the insulated cover, it will condense on the cold window surface. When the insulation is removed or opened in the morning, water damage will occur as the ice melts.

The various types of interior-window insulating systems include curtains, shades, blinds, and shutters. Drapes or rolling blinds are difficult to seal or to construct thick enough for very high insulation levels. *To be cost effective, any window insulation should have an RSI-value of at least 1.0 (R 5.7).* Shutters can be individual panels installed at night and stored away during the day, or sliding or hinged units (Figure 6-14).

There are a number of commercial products available as drapes, shades, and blinds for window insulation. When comparing them, you should evaluate cost, adaptability to the type of window used, and ease of use. Window insulations can also be custom made. But, when considering options, remember to take into account not only cost and ease of use but also storage, combustability, and appearance.

Some window-insulating systems operate by adding an insulating material between the layers of glass. One technique used is rolling reflective blinds. Another involves filling the space between the glass with an insulating material such as styrofoam beads. These methods are generally quite expensive and require specifically designed openings for proper installation.

b) Exterior-Window Insulation

Exterior-shutter systems have some advantages over interior-window ones. Sealing them against air leakage is not as important, since condensation will not occur on the outside of the glass, the shutters can prevent summer overheating, and combustability is not a serious problem. However, *operating exterior shutters can bring problems.* Any pulley or arm system operated from the inside will create a break in the air-vapor barrier and may lead to air leakage. And operating the shutters from the outside is definitely an inconvenience (Figure 6-15).

N.B. *Shutters should fit under the eave so that snow build-up is not a problem.*

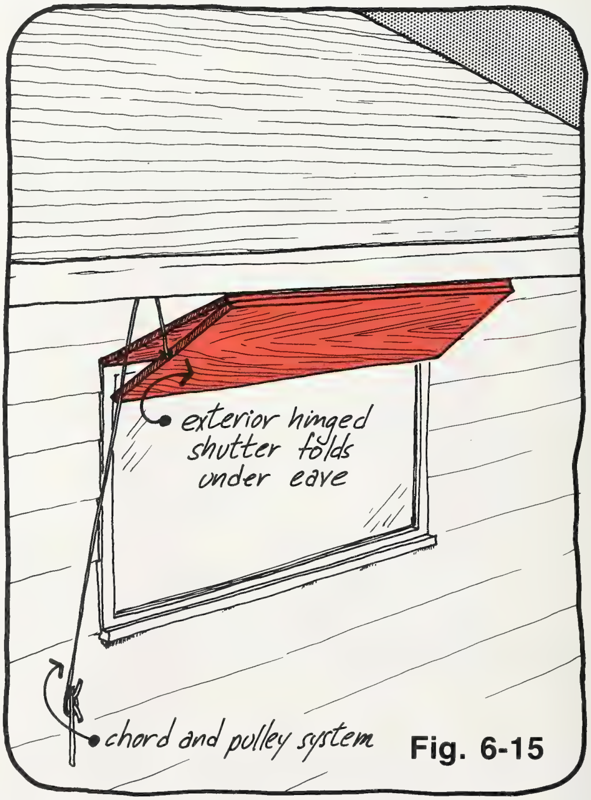


Fig. 6-15

Summary

Taking advantage of passive solar energy is a very convenient step when taken into account at the design stages of home planning. The following aspects are essential to keep in mind:

- Orient the house structure along an east-west axis so that the longer side faces south and is exposed to the maximum amount of solar radiation.
- Keep windows to a minimum on north, east, and west elevations.
- Incorporate overhangs to prevent summer overheating.
- Use exterior wall-finishing materials that are dark-colored—to absorb winter solar radiation.
- Use roof-finishing materials that are light-colored—to reflect summer solar radiation.
- Incorporate windows that open to permit cross-ventilation.
- Build thermal mass into the home if the window area facing south exceeds 8% of the total floor area.
- Triple glaze all windows.
- Utilize a form of window insulation.
- Provide berms, evergreen trees, and/or fences to give wind protection in winter.
- Use evergreen trees to protect east- and west-facing windows from excess solar radiation.
- Use deciduous trees on the south for summer shading.

Combining all the above factors with high insulation levels and a well-sealed air-vapor barrier will ensure an energy-efficient home.

EXISTING HOMES: KEEPING THE HEAT IN

OUTLINE

This portion of the *Energy-Efficient Housing* series is an overview of what will be described and illustrated in more detail in six programs on improving existing homes. These programs deal with renovations, specifically with simple methods of controlling heat loss, substantial remodelling solutions that produce energy-efficient upgraded homes, and operational hints that will help lower home energy requirements. The topics covered include principles of heat loss, economics of fuel use, aspects of renovation, types of heating systems, and owners' lifestyle. The programs explore, in depth, the various construction techniques and operational aspects of retrofitting.

A. Retrofitting

1. What Is It?

Retrofitting is defined as "renovating to lower home energy requirements." In other words, any changes made to an existing house to make it more energy-efficient. Changes vary from adding a little weatherstripping to completely wrapping the house in insulation. An energy-efficient renovation can be described as resulting in a house that uses only one-half to one-third the amount of energy needed to operate a similar-size structure that has not been retrofitted.

Energy is required for space heating, domestic water heating, appliance operation, ventilation requirements, and for lighting. The greatest energy requirement is for space heating—up to 70% of the total requirement in most homes—and so an energy-efficient home is one in which that demand has been drastically reduced. Table 7-1 shows standard home energy consumption versus that of a retrofitted home of similar size. (Table 7-2 gives metric to Imperial conversions used in the programs.)

Table 7-1 HOME ENERGY REQUIREMENTS

	Hot Water(%)	Elec.(%)	Space Heat(%)	Total
Standard Home	40 GJ*(18)	30 GJ(13)	155 GJ(69)	225 GJ
Retrofit	30 GJ(27)	30 GJ(27)	50 GJ(46)	110 GJ

*gigajoules

The units of energy used in Table 7-1 are gigajoules, but the actual unit used to measure the fuel is irrelevant; it is the ratio that is interesting to note. The total fuel use for an energy-efficient retrofit is *less than 50% that of the standard home.* The largest saving is in the area of space heating.

Table 7-2 TYPICAL METRIC CONVERSION FACTORS

1W (watt) = 3.412 btu/hr.	1mm (millimetre) = 0.039 in.
1 GJ = 948,000 btu	1m (metre) = 3.28 ft.
1 RSI = 5.71 R	$1m^2$ = 10.76 $ft.^2$
	$1m^3$ = 35.3 $ft.^3$
1 L (litre) = 0.22 gal.	1 kg. (kilogram) = 2.205 lb.

2. What Should It Cost?

A great many things can be done to the average home to make it energy-efficient. Some are very inexpensive while others are quite costly. However, any investment in energy conservation has to be looked at in terms of **simple payback**. For example, an extensive caulking job may cost $100 for materials, but if the homeowner does the labor, and $50 is saved on the first year's energy bill, the simple payback on that investment will be:

$$\frac{\text{Total investment: } \$100}{\text{Yearly savings: } \$\ 50} = 2.0 \text{ years}$$

Simple payback assumes that the rate of interest approximates the inflation rate in the price of fuel. If fuel prices rise slowly, the payback period will be longer; if they rise swiftly, the period will be shorter. An investment with a payback of two years is an excellent one.

Older homes with no improvement made to them in terms of energy efficiency will be consuming $3000-$5000 per year of energy in the not-too-distant future. *Retrofitting can reduce energy bills by at least one-half*—possibly more. Investing $5000 now in renovations may result in a very short payback period, depending on fuel type and price. A low-cost fuel such as natural gas, for example, involves longer payback periods than does such a higher-priced fuel as electricity.

Economics apart, there are many reasons other than saving energy for considering retrofitting an older home. These benefits include an increased comfort level due to the elimination of drafts, a quieter home due to higher insulation and air-tightness levels, higher levels of winter humidity due possibly to warmer interior surfaces, and a higher potential resale value.

B. Home Heat Losses

There are two major ways in which the typical house loses heat. One, which accounts for up to 40% of the total, is referred to as **air-leakage heat loss**. The other, making up the remaining 60%, is called **transmission** or **conductive heat loss**.

1. Air-Leakage Heat Loss

This type of loss occurs where air leaks in or out of the building envelope (the exterior shell of the structure). The average home changes its entire volume of air 24 to 48 times a day through this leakage—air that you, the homeowner, have paid to heat during the winter! In point of fact, the atmosphere in an average home will stay fresh and dry enough with only 8 or 10 air changes per day (one-third to one-half per hour).

Part of this excess air leakage is caused by hot air rising. It is constantly trying to leak out of any cracks, holes, or joints near the top of the house (Figure 7-1). Since it is impossible to create much of a vacuum in a home, this hot air is replaced by cool, outside air, which leaks in through cracks, holes, or joints in the lower part of the house. The cold air is heated to room temperature, causing it to rise and try to leak out. This whole process is known as the **stack effect**.

Air-leakage heat losses can be increased by the wind. Higher pressure on the windward side forces in cool air through any cracks or holes. Lower pressure on the leeward side draws hot air out (Figure 7-2).

Air-leakage heat losses are often termed "infiltration", because you can feel the cold air coming in or infiltrating. There is usually very little pressure difference between inside and outside. So, for every bit of cold air that is coming in, there is an equal amount of warm air exfiltrating.

2. Transmission Heat Loss

Transmission heat losses occur when heat moves by conduction, radiation, and/or convection through the materials that make up the walls, floors, ceilings, doors, and windows of a house (Figure 7-3). The rate of heat flow through any material, or combination of materials, depends on the resistance to heat flow and on the temperature (t°) difference from one side of the material to the other. Resistance to thermal flow is often referred to as the **R-value** in Imperial terms, and the **RSI-value** in metric: the higher the R-value or RSI-value, the better the thermal resistance.

Thermal-resistance values are given for a number of different building materials in Table 7-3. The total resistance value of any building surface is the sum total of the values of each layer (Figure 7-4). To calculate the rate of heat

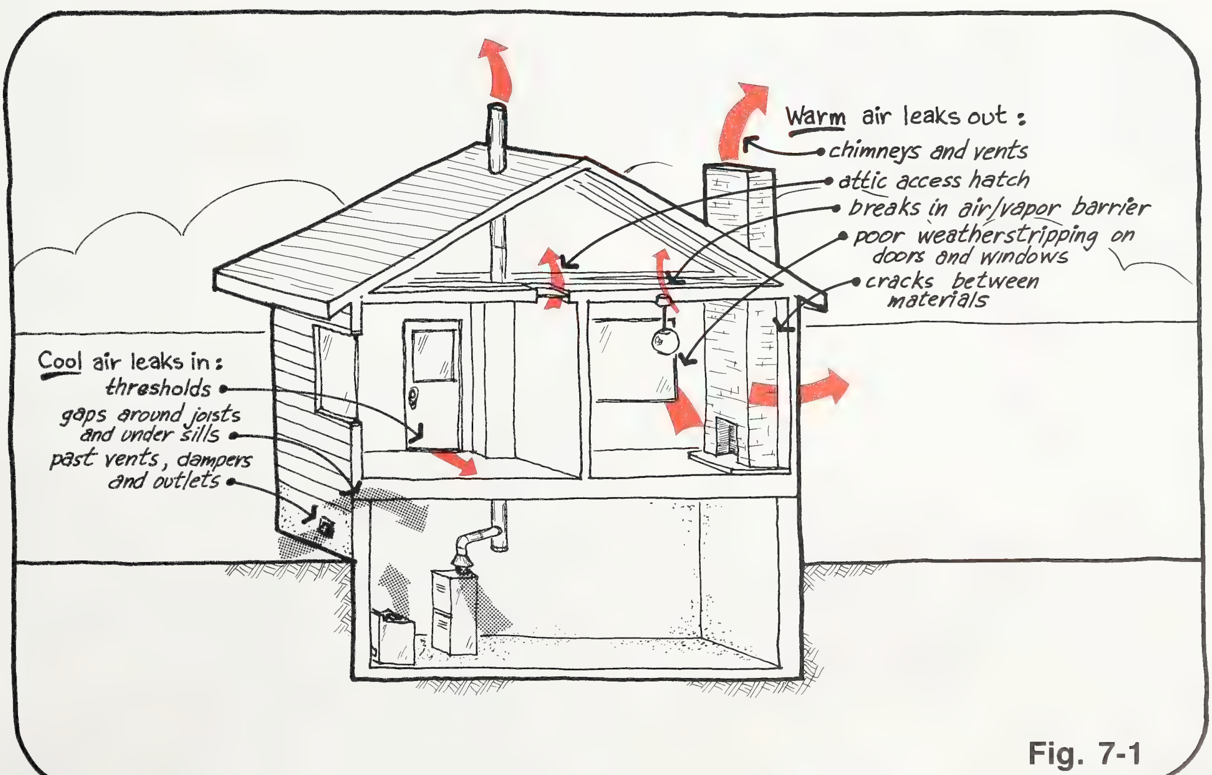


Fig. 7-1

Fig. 7-2

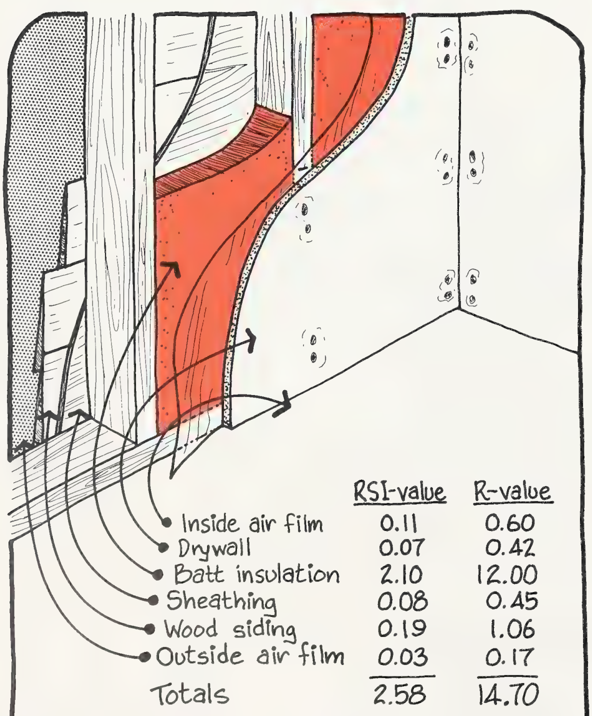


Fig. 7-4

loss through any surface, the following equation is used:

$$\text{Heat loss} = \frac{\text{surface area} \times t^\circ \text{ difference}}{\text{thermal resistance value}}$$

In this equation, heat-loss values will be in **watts** if the area is calculated in square metres, the inside to outside temperature difference is given in °C, and the thermal resistance is measured in RSI-values. The heat loss will be in **British Thermal Units** (btu) if the area is in square feet, the temperature difference in °F, and the thermal-resistance value in R-values. The total transmission heat loss from a house can be calculated by adding up all the losses from individual components—walls, windows, doors, floors, and ceilings.

Table 7-3 THERMAL RESISTANCE VALUES OF BUILDING MATERIALS

Material	RSI-Value	R-Value
Inside air film	0.11	0.60
12mm (1/2") wallboard	0.07	0.42
19mm (3/4") wood boards	0.17	0.94
12mm (1/2") air space	0.17	0.94
Window glass	0.006	0.03
90mm (3 1/2") solid wood	0.77	4.38
200mm (8") concrete	0.26	1.49
90mm (3 1/2") glass fibre	2.10	12.00
25mm (1") expanded polystyrene	0.69	3.96
25mm (1") extruded polystyrene	0.87	4.96
25mm (1") rigid glass fibre	0.74	4.25
25mm (1") rigid urethane/isocyanurate	1.31	7.50
150mm (6") cellulose fibre	3.80	21.70
150mm (6") wood shavings	2.54	14.50
150mm (6") blown glass fibre	2.43	13.90
150mm (6") expanded vermiculite	2.16	12.35
9mm (3/8") sheathing	0.08	0.45
12mm (1/2") hardboard siding	0.13	0.73
19mm (3/4") wood siding	0.19	1.06
15mm (5/8") stucco	0.02	0.12
Metal/vinyl siding with backing	0.25	1.41
Carpet (synthetic backing)	0.23	1.29
Hardwood flooring	0.12	0.69
Outside air film	0.03	0.17

It is very important to remember that heat moves by transmission from warm to cold *regardless of direction*—up, down, sideways, or on an angle! (It is only hot air that rises.) Because heat moves in all directions, it is essential to increase the resistance to heat flow of the walls, ceilings, *and floors*. Increasing resistance values is done with insulation. Types of insulation materials, where they should be used, and how to apply them in retrofitting situations are matters that will be explained in the programs that follow.

3. Diagnosing Home Heat Losses

Some very sophisticated methods are available for examining an existing home and diagnosing areas of heat loss. Thermography involves the

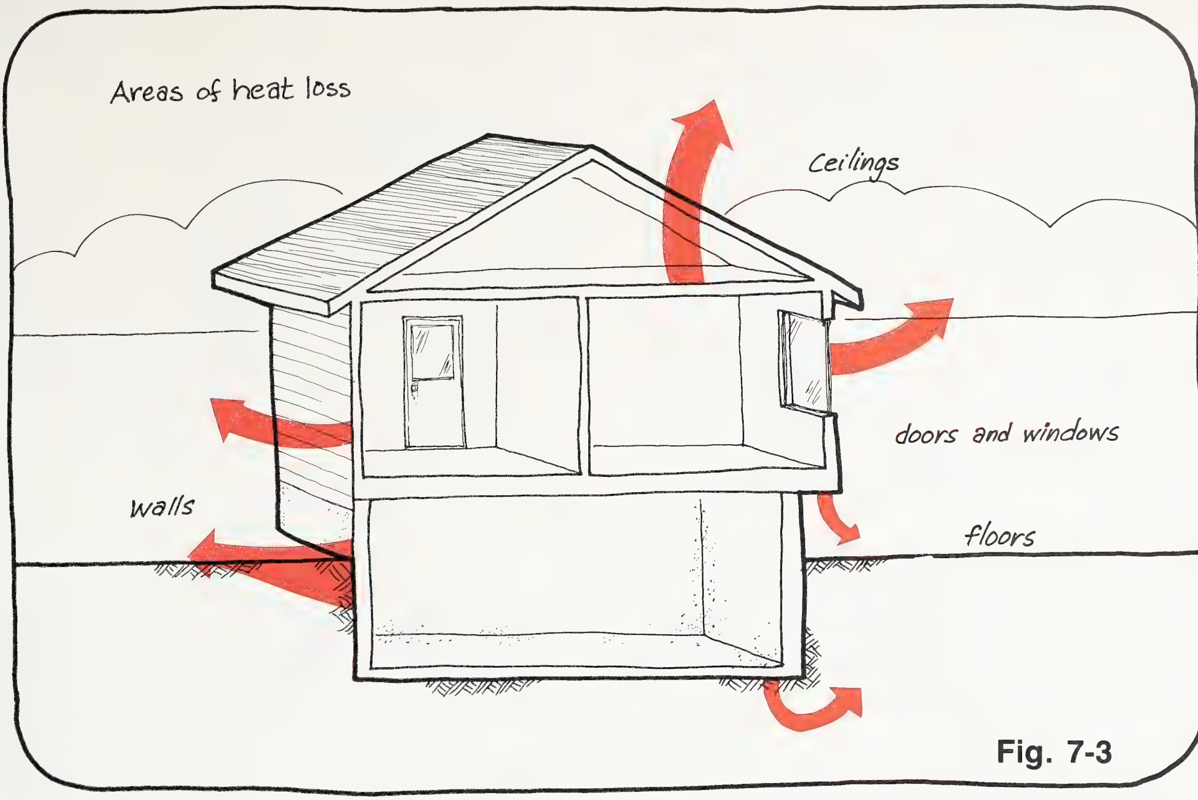


Fig. 7-3

use of sensitive infra-red cameras, which can accurately show areas on the exterior of a home that are minutely warmer than others—and therefore are leaking heat at a high rate. The cameras can also be used on the inside, where cooler areas indicate areas of high heat outflow. Large wall or ceiling areas exhibiting heat loss may indicate lack of insulation, while lines that register on the viewing screen along potential crack areas indicate air leakage.

Infiltrometers are devices which create an artificial vacuum in a home, using a powerful fan unit positioned in a door or window. The pressure differential created between inside and outside is registered, the volume of the house taken into account, and a calculation made estimating the natural air-leakage rate. The harder it is to create a vacuum (i.e., the faster the fan has to run), the leakier the house being tested. While the house is under a vacuum, potential air-leakage areas are tested with a smoke pencil.

The use of thermography or infiltrometers can be expensive. And, in fact, with a little investigation, you can easily determine on your own where insulation is lacking. Look up in the attic, behind any kneewalls, under storage space floorboards, and in the basement and any crawlspaces

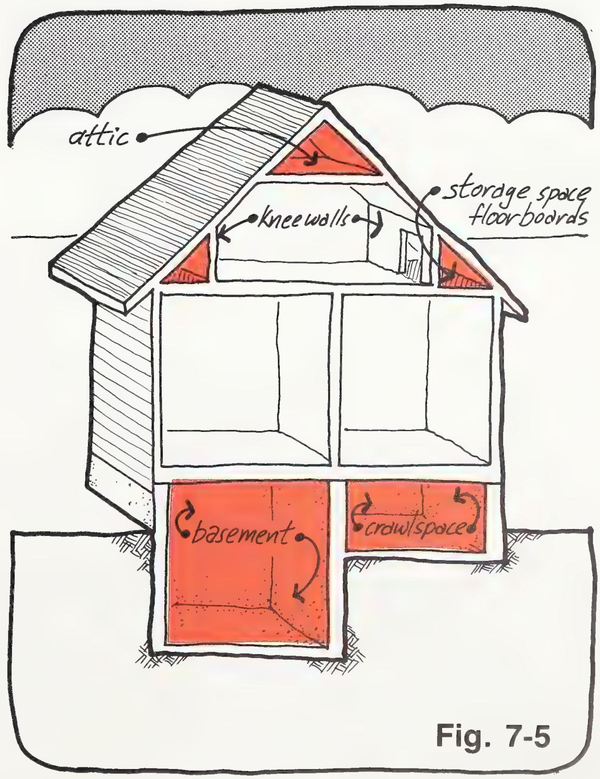


Fig. 7-5

(Figure 7-5). See if there is *any insulation*, if there are *any gaps* in existing layers, or if there are *any thin spots* in what insulation there is. To check finished walls, turn off the power and remove a few switch and outlet covers. Often, you can look alongside the electrical boxes and ascertain the type of insulation present. If you can't, probe in beside the boxes with a bent coathanger to draw out some material (Figure 7-6). (Keep the power off until you have finished and have replaced the outlet covers.)

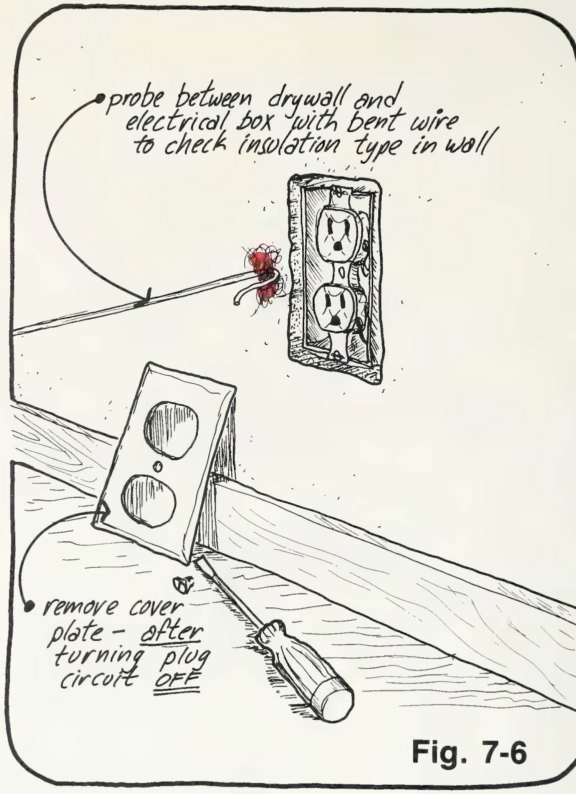


Fig. 7-6

Sources of air leakage in a home are easily detected. By holding a piece of smoldering cotton string, a cigarette, a piece of incense, or any (commercially available) smoke pencil near suspected areas of air leakage, paths of incoming air can be identified (Figure 7-7). Checking for air leakage should be done on a cool and windy day, with all the exhaust fans in the home turned on to create as much of a vacuum as possible. Potential sources of air leakage include the framework around windows and doors, at electrical outlets, along baseboards, around milk chutes, in joist spaces, next to weatherstripped areas—in general, any place where two different materials or surfaces meet. Mark any places where air leakage is detected for caulking, weatherstripping, or gasket installation. (These matters are discussed in detail in later programs.)

Sources of air leakage not only allow heat to escape, they also transmit moist air. Humid air passing by cold surfaces will create condensation inside wall, ceiling, floor, and attic assemblies. This can cause deterioration of such structural components as joists and studs. Look for any frost or ice build-up during cold weather as indications of air leakage. Gaps or holes should be repaired and sealed to avoid further problems.

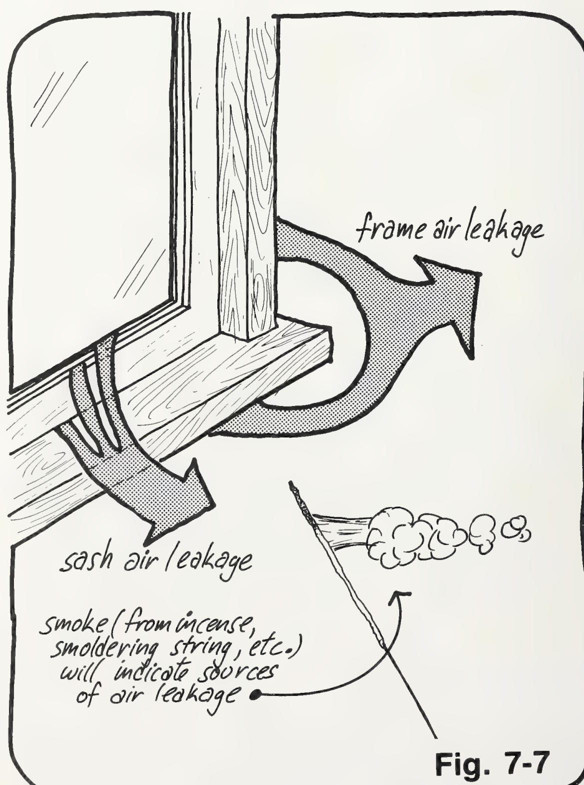


Fig. 7-7

C. What To Do About Heat Loss

A combination of common sense and economics will help a family decide what is best in their situation. If there are any areas of easily detectable air leakage, these should be a first priority. If any areas of the home are not insulated, these, too, should be a major priority.

An uninsulated basement can be robbing your home of 30% to 40% of the total heating energy. If your attic already has some insulation in it, then that uninsulated basement should be renovated quickly. If the basement is already insulated, then consider adding insulation to the attic or walls, although the economic benefit is not as great—there will be a much longer payback period on your investment.

Many aspects of retrofitting can be small, easily accomplished steps on the way to an energy-efficient structure. Often, homeowners do three or four minor jobs a year—e.g., installing weatherstripping or caulking—because they have neither the time nor money to do a major retrofit.

A major retrofit can involve completely rebuilding walls and roofs to accomodate higher insulation levels, and the installation of a well-sealed air-vapor barrier. A solution as drastic as this is only economically justifiable if new siding and roofing is required. In other words, the retrofit is combined with a planned major renovation that is necessary in any case. This will involve many thousands of dollars and may not be feasible just in terms of energy saving. However, such other aspects as comfort, extended home life, and increased resale potential are factors relevant to a retrofit-cum-renovation.

When any modifications, changes, or new equipment are needed in an existing home, you should always explore what is available in terms of products that use less energy. If replacing a furnace, hot-water tank, or other appliance, choose an energy-efficient one. When replacing window units, pick models with good seals, and make sure that they are properly installed. If adding on to your home, make sure that the addition is constructed with lots of insulation and a well-sealed air-vapor barrier. If possible, design the addition to capture some passive solar energy through south-facing glass. Should you be doing any landscaping, consider evergreen trees on the north and west sides to provide wind protection. Plant deciduous trees on the south and east. They provide excellent summer shading as well as allowing the winter sun access into the home.

1. Planning

A homeowner's formulation of a planned attack on sources of heat loss is an important step in retrofitting. This will force you to set out the tasks you want to undertake, goals you want to reach, and a schedule you can follow. Added to which, financial requirements can be anticipated and budgeted.

Renovations require building permits. Even small changes to your home may require changes to utility hookups or site coverage. Planning ahead will enable you to obtain any necessary approvals from authorities in your area.

2. Lifestyle

There are many small things you can do, as routine habit, to improve the energy efficiency of a home:

- Turn off all lights and appliances in spaces not being used.
- Light only those areas in active use.
- Arrange spaces and work areas to take advantage of natural light through windows.
- Set back the temperature at night, and also during the day when no one is at home.
- Keep drapes closed at night and open on sunny days.
- Use appliances efficiently—full loads in dishwashers, dryers and clothes washers, filters cleaned regularly, utilizing cold-water washes where possible.
- Install water-saving devices on toilets, showers, and faucets.

Summary

Owners of existing, older homes face very high energy costs in the future because energy costs are always increasing—and bills of $3000 to $5000 per year will not be uncommon. Yet there are many simple ways to lower energy consumption, as will be illustrated in subsequent programs.

Every existing house has its own particular problems. Every individual family has its own unique lifestyle. However, there are common areas that can be looked at in any home, when upgrading energy efficiency. And every family can do a lot to alter its energy-use habits and realize savings on fuel bills.

EXISTING HOMES: PLUGGING THE HOLES

OUTLINE

Air leakage (infiltration and exfiltration) can account for anything up to 40% of the total heat loss from a house. This leakage occurs around windows and doors, through cracks between materials, around ducts, pipes and conduits, up chimneys, past loose exhaust dampers, and alongside electrical fixtures.

This program details what can be done to lower air-leakage heat losses from existing homes. There are a number of techniques, most of them quite simple, that can be applied to different areas of a home to stop thermal flow through the walls, ceilings, and floors. Care taken in identifying and sealing sources of heat loss will result in quite substantial energy-cost savings.

A. Air-Leakage Heat Losses

The average home has a volume of about 550 cubic metres of air (or 19,000 cubic feet—Table 7-2 lists some common metric-to-Imperial conversions). This warm air tends to leak out and be replaced by cold outside air at the rate of at least one total house volume per hour in existing structures. This rate can be reduced by one-half or more by sealing up as many air-leakage sources as possible. By not having to heat all this excess infiltrating air, a potential saving of 10% to 20% on the annual fuel bill is possible.

Uncontrolled air leakage through a poorly installed (or non-existent) vapor barrier, past windows and doors, up chimneys and ducts, and out any cracks and holes is caused by the stack effect and by wind pressure, as explained and illustrated in previous programs. These losses are termed "infiltration" because you can feel the cold air coming in or infiltrating. Since there is little pressure difference between inside and outside, there is an equal amount of exfiltration.

The following five sections discuss the major sources of air-leakage heat loss and illustrate methods of sealing them. (Refer to Program Seven for a description of how to detect areas of severe air leakage.)

Although the air-vapor barrier (assuming one is in place) plays the major role in controlling air leakage, when renovating a home, caulking and weatherstripping are the two main "tools" to use in sealing gaps. (Older homes may not have an air-vapor barrier, and installing one is very difficult.) Caulking and weather-stripping materials are the sole means of controlling air leakage in some situations.

Caulking is used to seal gaps where two surfaces meet but do not move relative to one another—joins in different siding materials, frames around doors and windows, gaps around pipes and ducts, etc. Oil-based and resin-based caulks (e.g., putty) are quite inexpensive but only last for a few years. Latex and butyl rubber-based materials are more durable and adapt well to any surface, but cost more. The most expensive caulks are elastomeric ones (silicones and polysulphides), but they do provide the most durable and flexible seals—often lasting for 20 years or more. Polyurethane foam is a special type of material useful for sealing, especially wide gaps around rough openings, pipes, or along sill plates.

Weatherstripping is used to control air leakage at joints where two surfaces meet and move relative to one another, as, for example, windows that open. Testing has proved that tubular weatherstripping provides the best seal, if given the proper closing pressure—a disadvantage if children, the handicapped, or elderly persons use the openings in question. Vinyl or rubber strips are best in terms of least pressure and best seal. Open-cell foam and felt strips are not good air seals and tend to wear out quickly. The best weatherstripping materials are those that create a good air seal with a minimum closing pressure and have long, useful lives—vinyl or rubber strips, tubular, and expanded types.

Note that the type of window or door opening—sliding or hinged—has a bearing on the kind of weatherstripping to use.

1. Windows

Air leakage can occur past windows in three locations (Figure 8-1); between the glass and the frame; between the opening frame and the window jamb, and past the frame in the rough opening space.

If the leakage is occurring between the glass anc frame, the interior trim should be removed and the caulking replaced, using a latex or butyl type (Figure 8-2). *Caulking should be done on the inside as much as possible* to prevent warm, moist air from escaping and condensing inside the window assembly.

Leakage that occurs between the opening frame and the window jamb must be controlled with good-quality weatherstripping. The type to use will depend on the kind of opening window. If a vertical slider (often referred to as double hung), compressible products like vinyl tubes or expanded, closed-cell foams can be used along the sides, bottom, and meeting rail (Figure 8-3). If horizontal wood or metal slider, replacement

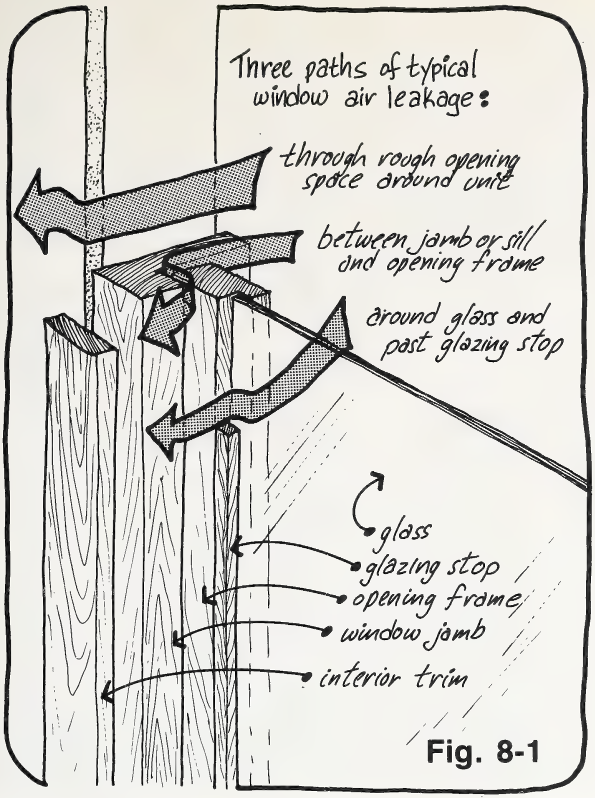


Fig. 8-1

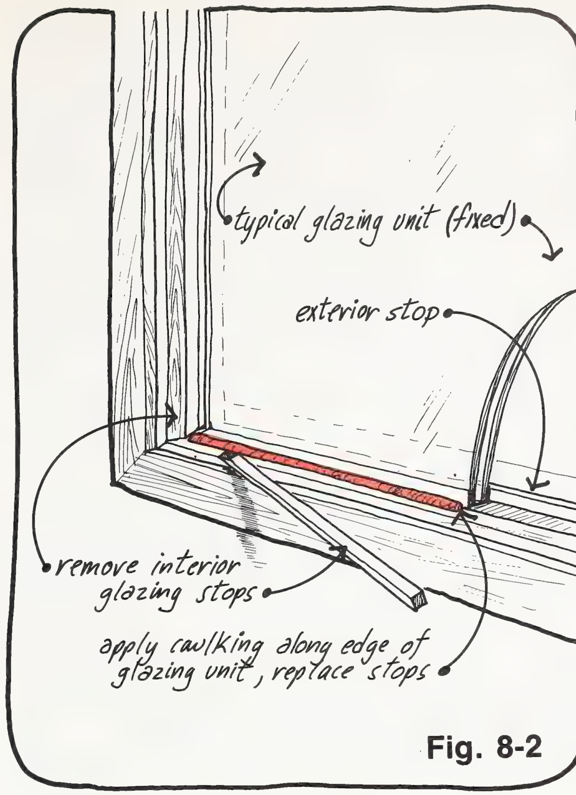


Fig. 8-2

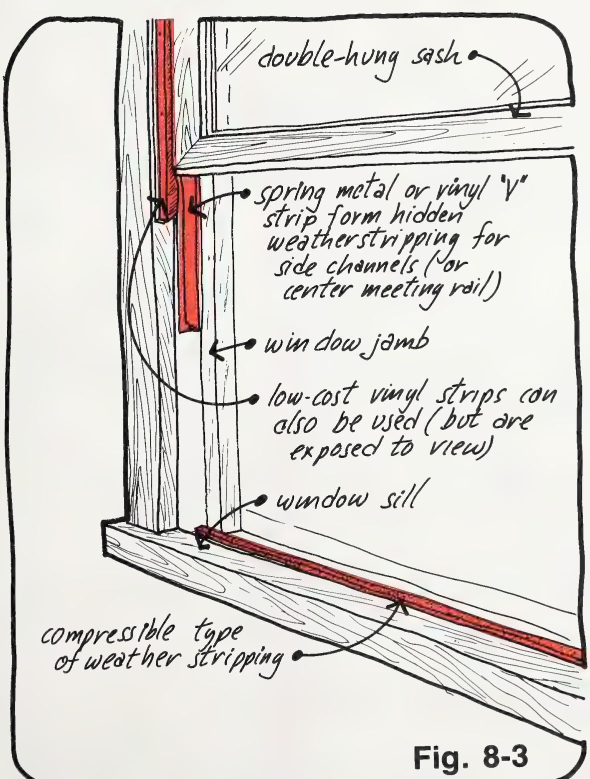


Fig. 8-3

vinyl pile weatherstrips are usually available from the manufacturer. Swinging windows can incorporate any number of good-quality compressible types. A number are illustrated in Figure 8-4. The self-adjusting types, those that have slotted holes allowing for future adjustment, are the best ones to use.

If leakage is occurring around the window trim (through the rough opening installation space), the best solution is to remove the trim and seal the gap properly. *The rough opening space should be loosely stuffed with insulation to control heat loss by conduction.* Then the space should be filled with a caulk on the inside (using a latex or butyl product, or expanding polyurethane foam if the gap is wide), or covered with a sealed strip of heavy polyethylene (Figure 8-5). The window trim is then reinstalled or replaced as required. Be sure to do this if you are removing the trim for painting or are replacing it for any reason.

Leakage through windows that are fixed, or opening ones that are not used during the heating season, can also be lessened by installing interior storm units. Available as clear plexiglass or heavy polyethylene, the units are

attached to the frame by interlocking strips or magnetic seals. Not only is leakage stopped, but the trapped air layer increases the insulation value of the window, too. (The units are easy to remove for the summer months.) Although add-on storms cover the window and frame, if there is air leakage on the outside of the frame, i.e., through the rough opening space, these storm windows will *not* help stop the leakage.

The remodelling stage is often a good time to improve on window quality and layout in the home. When replacing window units, choose well-built casement ones with good hardware and weatherstripping features. The additional expense is justified by lowered heat loss, ease of operation, less condensation, and general longevity. For the best insulation value, the frame materials should be wood or hollow-core vinyl. The rough opening must be well insulated and sealed when replacing window units. During extensive renovations, consider altering window locations to increase passive solar gains and cut down winter heat loss as well.

Heat losses around windows can account for 7% - 8% of the total heat loss from a home. Sealing the gaps and installing good-quality weather-stripping can cut this loss to 2% - 3%.

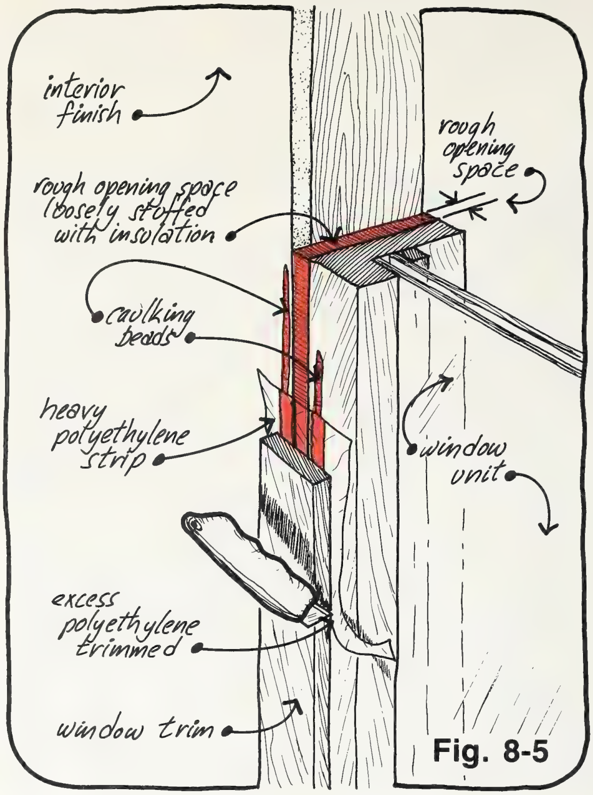


Fig. 8-5

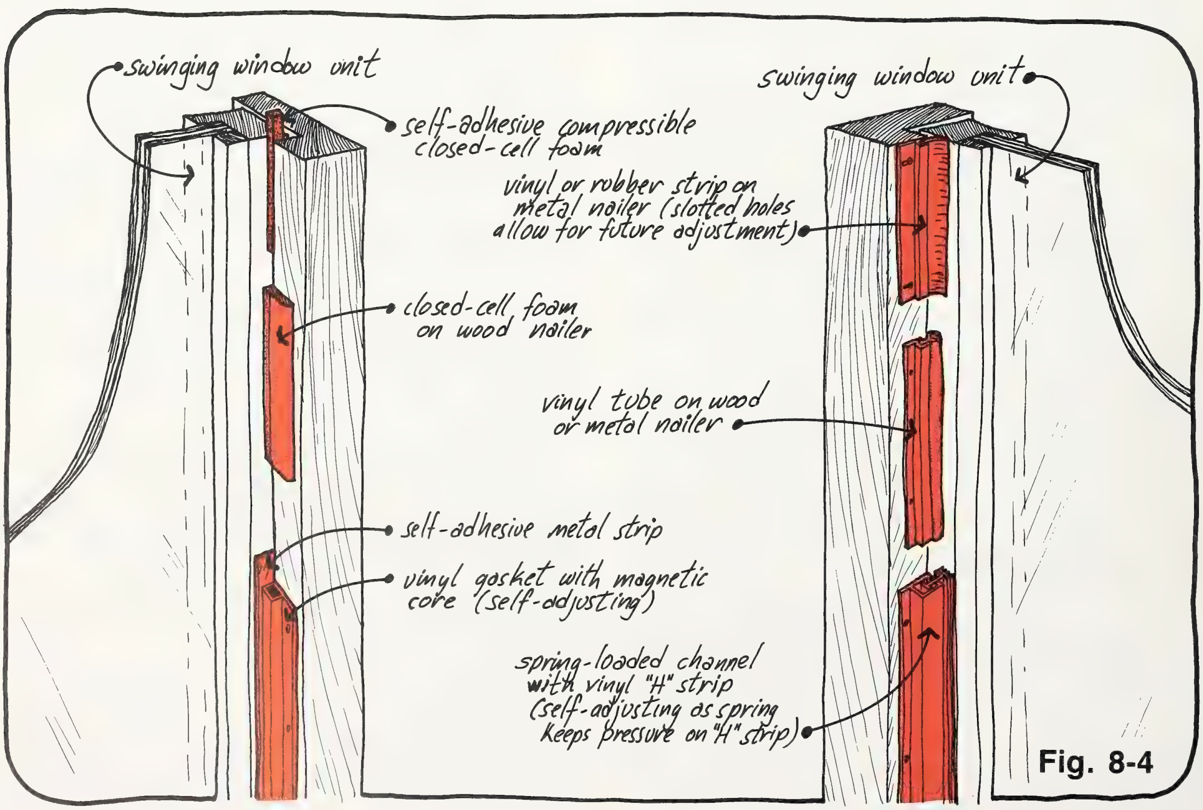


Fig. 8-4

2. Doors

Doors are prone to the same type of air leakage as windows. Their frames and jambs are of similar construction and are installed into rough opening spaces in like manner. Any glazing inserted in a door has to be resealed if leakage occurs around it (as in Figure 8-2).

When replacing weatherstripping around a door, first make sure that the door fits properly in the frame. Plane the door to ensure a uniform, even fit. Compressible weatherstripping can then be applied (Figure 8-4). The self-adjusting type, or those with slotted holes for future re-adjustment, are the best to use. If there is an indication of air leakage around the frame trim, i.e., through the rough opening space, then the techniques in Figure 8-5 can be used to seal that space.

The threshold of an exterior door presents a unique problem. Weatherstripping there must be very durable because of traffic wear. There are two ways to weatherstrip a door bottom—by using the threshold, or by attaching a door bottom or sweep. When choosing a door bottom or sweep, select one that does not require that the underside of the door be trimmed. Measure the clearance available and select accordingly. Some types, as shown in Figure 8-6, will adjust to accommodate different heights. Others attach to the side of the door bottom and require no clearance.

Thresholds are usually installed to replace existing ones that have worn out. Only the weatherstripping insert may be worn, however. Check to see if that part can be replaced, rather than going to the effort and expense of changing the entire threshold. If the insert does have to be replaced, buy one that is easily replaced.

Two other door-type openings in the home are mail slots and milk chutes. Both can be weatherstripped with compressible types of materials as illustrated for swinging windows and doors. If these openings are no longer in use, fill the gaps with insulation *and seal the openings from the inside with caulking.*

A final, exterior "door" that is often neglected is the attic access hatch. It can best be weatherstripped by using compressible tube or strip products, installed as in Figure 8-7. If the hatch is not heavy enough to create a tight seal, add fastening screws or latches to secure the hatch. It must also be insulated to at least two-thirds of the ceiling insulation value.

Heat losses around doors and the attic hatch can account for 3% - 4% of the total home heat loss. Sealing gaps and installing good-quality weatherstripping can cut this loss to 1% - 2%.

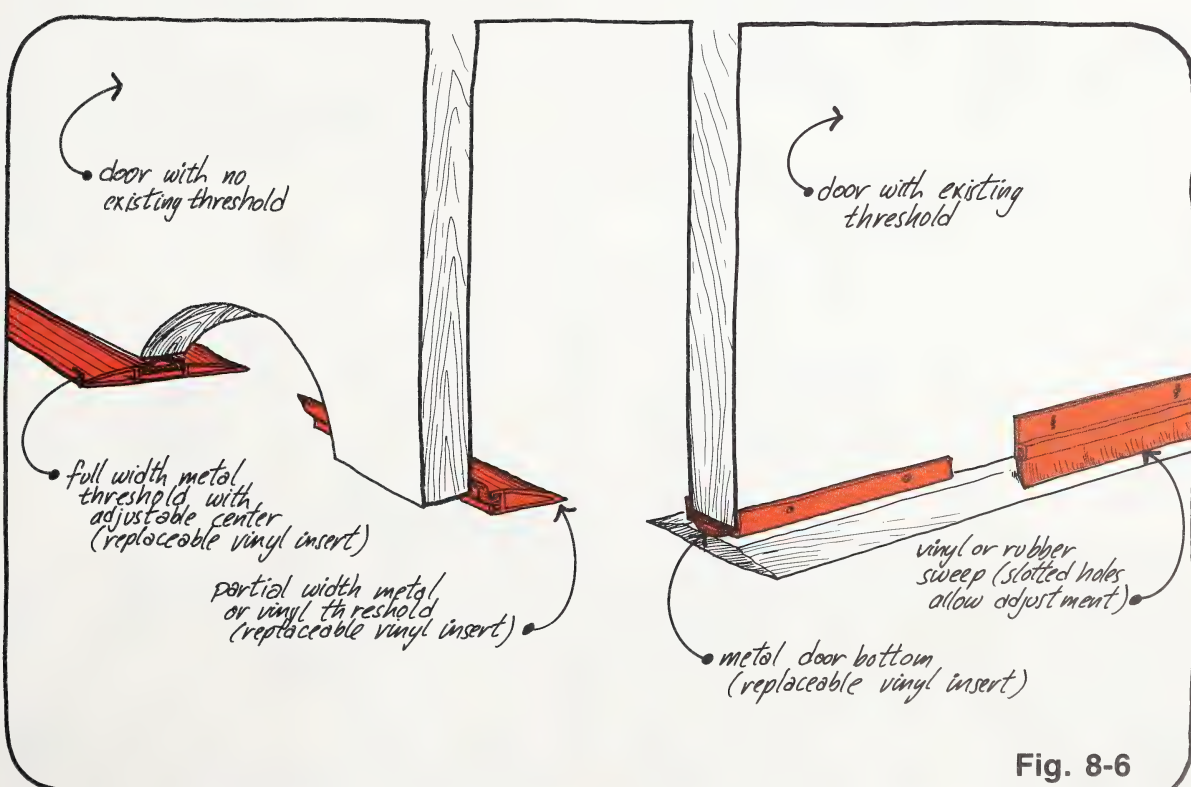


Fig. 8-6

3. Electrical Opening and Ducts

Outlets and switches on exterior walls are responsible for a large percentage of the total home heat loss—up to 8% in the opinion of some experts. In the past, holes in the air-vapor barrier around electrical outlets were accepted as normal building practice. However, sealing around these plates in an existing home has become very important because of this high rate of heat loss. There are two simple ways of stopping most of this air leakage.

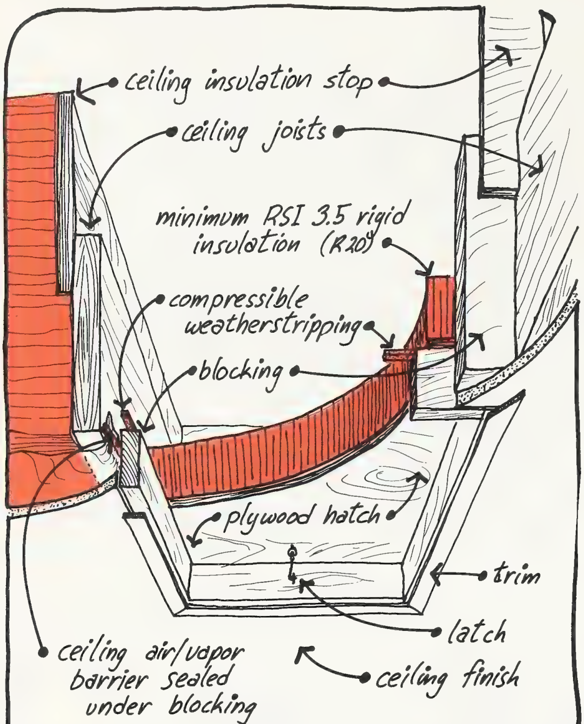


Fig. 8-7

Clear silicone caulking can be applied around the plates where they meet the wall and around the joints in the plate. However, making a neat job of this takes a lot of skill (Figure 8-8), and future removal of the plates is very difficult, if, for example, you want to install a dimmer switch.

An easier method is to use commercially available CSA-approved (Canadian Standards Association) gaskets under the plates. *After shutting off the power to the outlet*, remove the cover plate, install the gasket (Figure 8-9), and mount the plate back over it. Gaskets are available for switches, outlets, and ceiling fixtures. Two or three gaskets can be used beside each other for multiple switch plates. Child "safety plugs" can be installed in any unused outlets to stop air leakage through the holes (Figure 8-10).

Exhaust-outlet ducts are another source of air leakage. The dampers must be kept clean and enabled to open and close freely. Periodic cleaning is the best maintenance procedure. The fans should be used as little as possible in the winter since it is warmed house air that is exhausted, and cold air has to infiltrate in to replace it. Exhaust fans that are never used should be removed and the holes insulated and well-sealed.

Heat losses around outlets and through ducts and vents can amount to 10% - 11% of the total heat loss from the average home. Sealing the gaps and making sure all dampers are in good working order can cut this loss to 4% - 5%.

4. Caulking

Some specific uses of caulking have already been mentioned, in conjunction with other materials for stopping air leaks. There are also other areas where caulking should be applied to control air-leakage heat loss.

The joist space area of the home—where the wood structure meets the foundation wall—*is one of the worst single sources of air leakage.* This

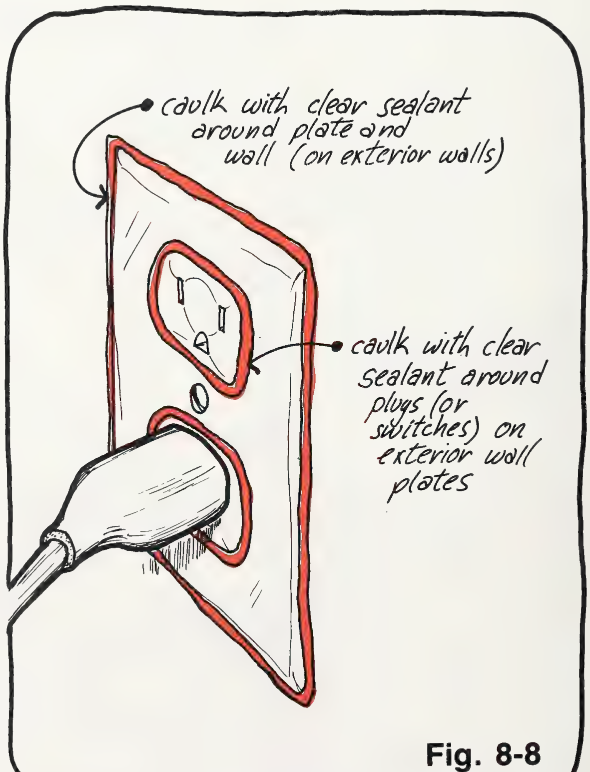


Fig. 8-8

Fig. 8-9

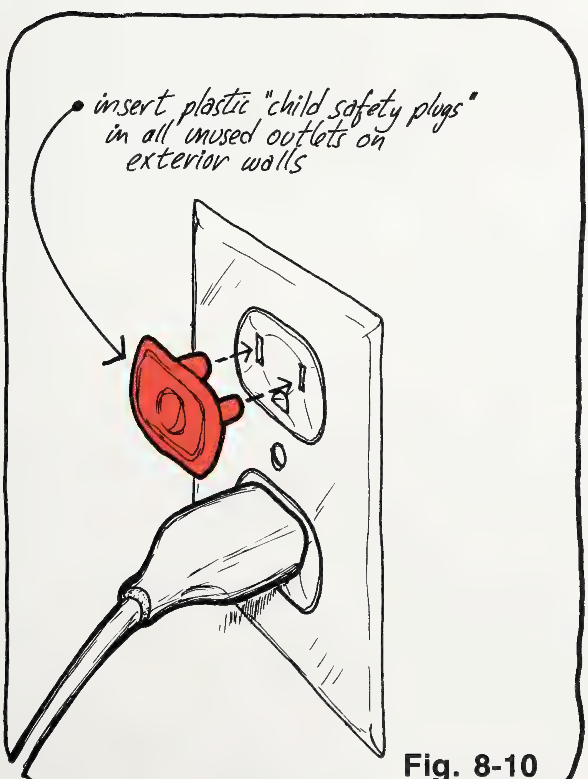


Fig. 8-10

space should be sealed from the inside as shown in Figure 8-11. Sealing on the inside will prevent warm, moist air from entering the building wall space and condensing as water and frost. This must be done before insulation is applied to the walls or joist space area.

The point where any ducts or conduits penetrate the building envelope should be well sealed. This may involve filling large gaps with a tightly stuffed material such as insulation or rope caulking, then applying a layer of good-quality caulking on top to complete the seal (Figure 8-12).

There may be gaps in building materials that cannot be caulked from the inside. In that case, apply the insulation on the outside. In addition, some exterior caulking may be necessary to protect materials from penetration by rain water and subsequent damage from frost or dry rot. Choose the best-quality materials for exterior caulking—silicones or butyl rubbers—because exposure to the elements will quickly deteriorate inferior ones.

Heat losses due to poor or non-existent caulking in joints, gaps, and around pipes and ducts may be contributing up to 10% of the total home heat loss. Adequate caulking with good quality materials can reduce this to 4%.

5. Chimneys and Stacks

In addition to electrical ceiling fixtures, there are a number of potential air-leakage sources in the attic of a home. Chimneys and plumbing stacks are two major areas that require sealing.

Metal chimneys usually penetrate the ceiling through a metal firestop. The firestop must be sealed to the ceiling surface or to the air-vapor barrier. Further, the metal chimney should be sealed to the firestop with a heat-resistant caulking. A metal sleeve around the chimney (Figure 8-13) will keep loose-fill insulation away from the warm chimney surface.

Older style masonry chimneys are more difficult to deal with. A tight-fitting collar made from scrap drywall material can be fashioned and sealed around the base (Figure 8-14). This will eliminate most of the air leakage.

Metal plumbing stacks common to older homes can be sealed as in Figure 8-15. A flexible neoprene or polyethylene collar is made and sealed to the stack and existing ceiling air-vapor barrier or surface. The collar should be kept tight to the stack by means of a pipe clamp. The flexible collar allows the stack to move up and down freely with expansion and contraction, yet maintains an airtight seal.

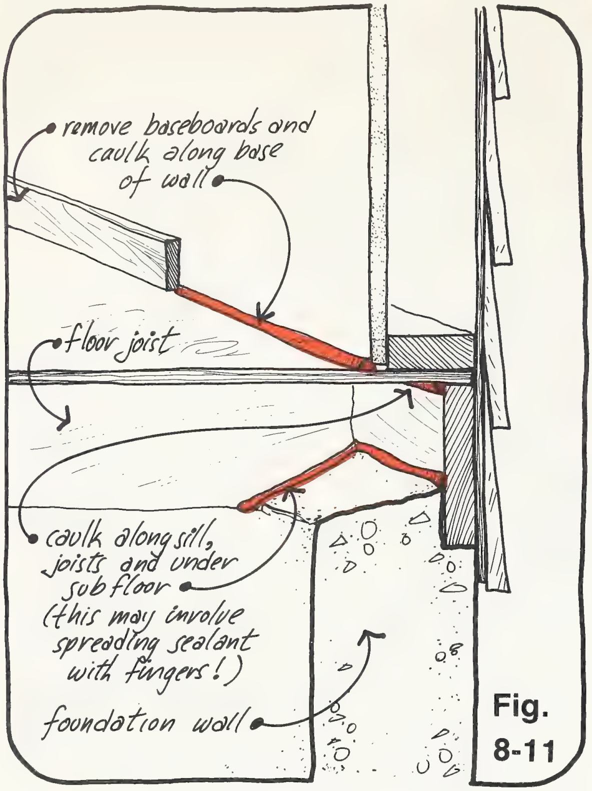


Fig. 8-11

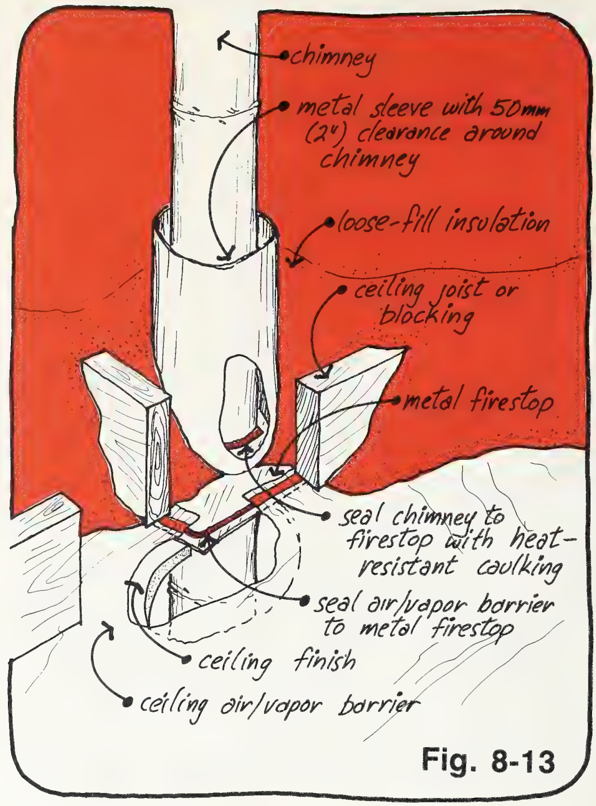


Fig. 8-13

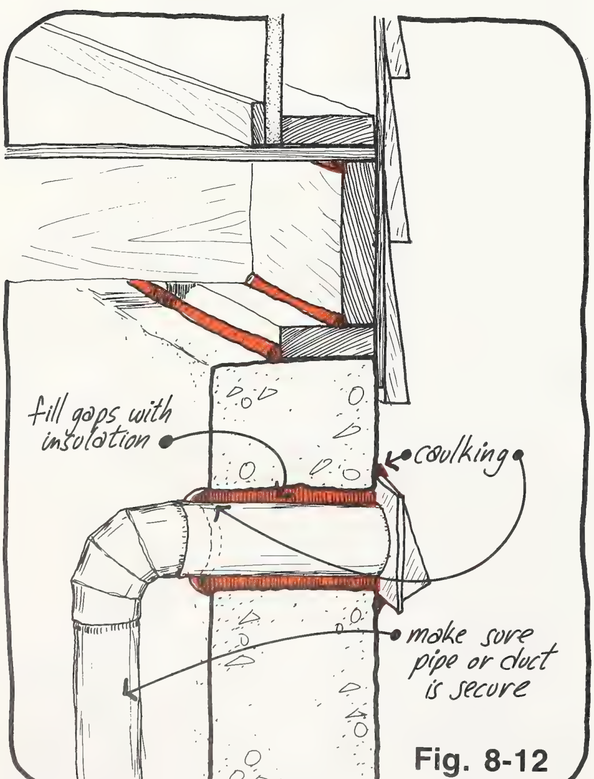


Fig. 8-12

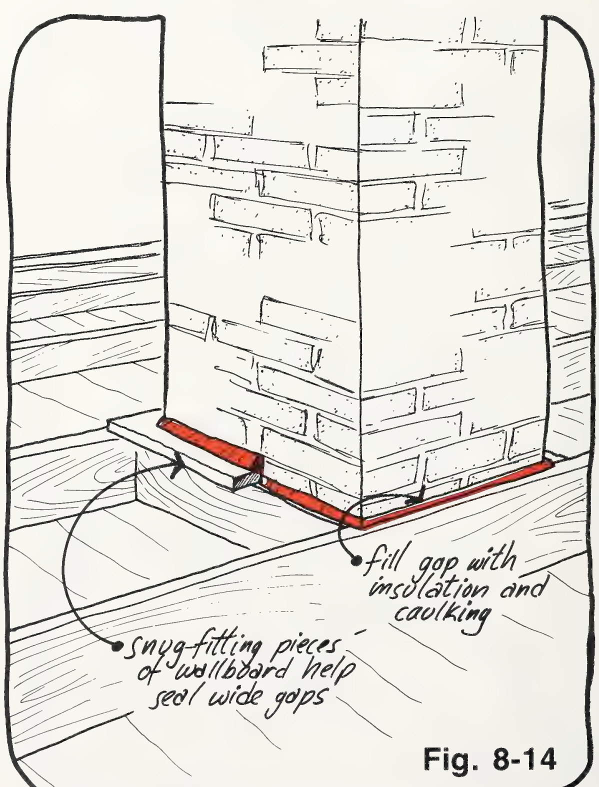


Fig. 8-14

As well as being sealed where they penetrate the ceiling, fireplace chimneys have dampers, which must be in good working order to prevent air leakage up the inside of the chimney flue. Check to see if there are gaps caused by debris, warping, or poor construction. The damper cannot be weatherstripped but can be cleaned or adjusted for a better fit. If the damper does not fit snugly, consider plugging the opening when the fireplace is not in use—or permanently if the unit is never used. As in Figure 8-16, a decorative insulated fireplace insert can be constructed to act as a "plug", which will prevent heated room air from being lost up the flue when the fireplace is not in use.

Heat losses past gaps around chimneys and stacks and up leaky fireplace flues can account for 5% of total home heat loss. Proper sealing of these areas can reduce this to 2% or less.

Summary

The major areas of heat loss described in this program account for almost 40% of the total loss from the average home. Sealing leaks around windows and doors, pipes and ducts, electrical outlets, and chimneys and stacks can easily reduce this total to 15%.

Eliminating these areas of air leakage will not only lower energy bills. Your home will be more comfortable, too. Of course, it is virtually impossible to eliminate all air leakage completely, for supplies of fresh air have to come into the home. All the sealing techniques illustrated, however, are easy for the homeowner to do and *do not involve a lot of expense.* Investing a little time will return large benefits in terms of comfort and fuel saving.

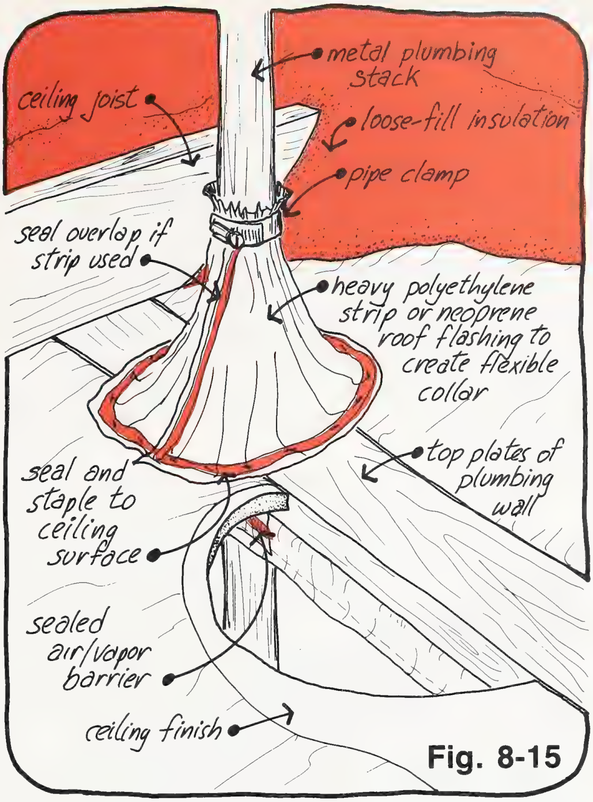


Fig. 8-15

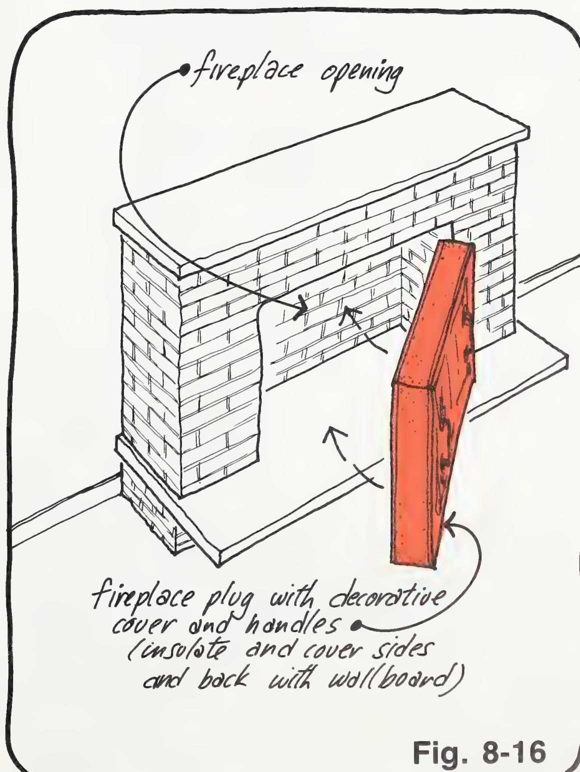


Fig. 8-16

EXISTING HOMES: BASEMENTS AND ATTICS

OUTLINE

Heat losses by transmission through the building shell of an existing home can account for 60% of the total heat loss. These losses occur when heat *conducts, convects,* or *radiates* through the walls, floors, ceilings, doors, and windows.

This program details what can be done in terms of adding insulation and an improved air-vapor barrier to control heat losses from basements and attics. A number of techniques illustrate how to attain insulation levels that result in energy-efficient retrofits.

A. Transmission Heat Loss

The transfer of heat through any material occurs, in large part, by conduction. The rate of heat flow depends on a material's *thermal resistance* (R-value or RSI-value) and on the *temperature difference* between one side of the material and the opposite side. The greater the temperature difference between the inside of a house and the outside, the "faster" heat will flow through walls, floors, and ceilings. (The formula to calculate heat flow is shown on page 56.) Higher levels of insulation—i.e., resistance to heat flow—will slow down the flow but never stop it completely as long as there is a temperature difference between inside and outside. High insulation levels will also slow heat flow from outside to inside on hot summer days.

Analysis has shown that the levels of insulation in Figure 9-1 are the most economic to use in the cool climate zone of the Canadian prairies and of the American Midwest. These are levels that you should try to attain when renovating for energy conservation—or **retrofitting**. Note that the lowest levels are shown for below grade because, in winter, the earth never becomes as cold as the outside air. In addition, slightly higher levels are indicated for the ceiling since the warmest air in a home with poor air circulation will "sit" at that level (because warm air rises).

B. Insulation Materials

The value of insulation is measured in terms of its resistance to heat passing through it—its **R-value** in Imperial terms or **RSI-value** in metric terms. The higher the R-value or RSI-value, the better the resistance to heat flow. (Table 7-2, on page 54, lists common Imperial/metric conversions.)

Insulation works by using air, an excellent insulator as long as it is not allowed to flow by convection. (The action of warm air rising and cold air falling creates convection.) Convection is

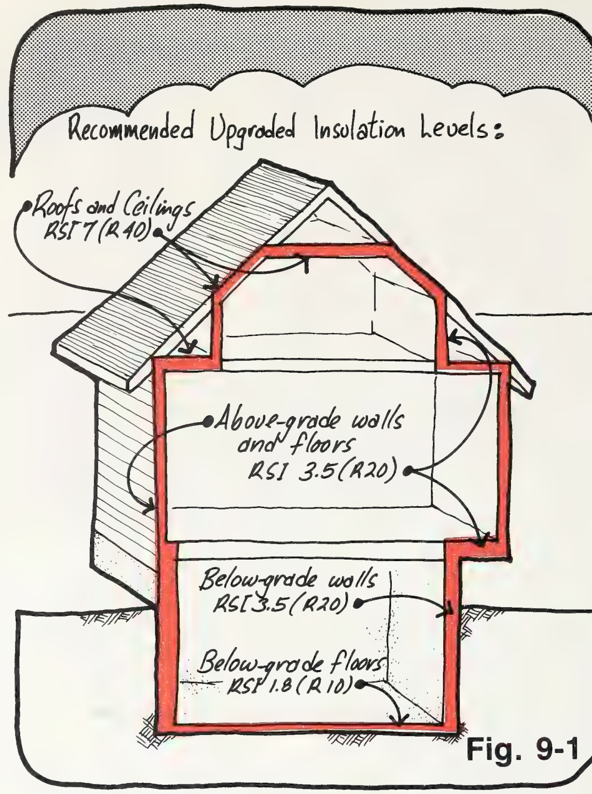


Fig. 9-1

not a problem if the air is contained in small pockets—friction prevents it from flowing readily. The best insulation materials contain many tiny air-filled cells in cavities created by very light materials such as paper, glass fibres, or plastic balls. The tiny air cells inhibit convection, while the lightweight cell materials inhibit heat flow by conduction.

The resistance to heat flow of a building assembly such as a wall or ceiling is the sum total of the RSI-values of the layers, as shown in Figure 7-4 on page 56. (The resistance values of common building materials are given in Table 7-3 on page 56.)

Insulation materials come in a number of forms. There are three basic types on the market: blanket; rigid; and loose-fill. Their individual characteristics and composition make certain types more applicable to some jobs than others.

1. Blanket Insulation

Blanket (or batt) insulation is easy to handle, its materials being made of either glass or mineral fibres. These very uniform products are manufactured in specific widths and thicknesses to match stud or rafter depths and spacings. They are in the medium-cost range and have an RSI-value of 0.6 per 25mm of thickness (R 3.5 per

inch). Because of uniformity and handling ease, blanket insulation is applicable to most situations in retrofitting—adding attic insulation, insulating previously uninsulated walls or installing interior basement insulation.

2. Rigid Insulation

Rigid (or board) insulation materials are also products made in specific thicknesses and widths. They are composed of styrene, isocyanurate, urethane, or glass fibres. Insulation values vary from 0.6 to 1.3 per 25mm of thickness (R 3.5 to 7.5 per inch). Costs vary from moderate to expensive.

It is important to note that *any plastic type of insulation used on a house interior must be covered with drywall or plaster.*

In retrofitting situations, the high cost of rigid materials rules them out for most applications. So use them where you need the *most* resistance in the *smallest* possible space. Adding insulation to a sloping ceiling is an example. Some types of rigid materials are suitable for earth burial (extruded polystyrene, rigid glass fibre) and so are quite useful for exterior basement insulation.

3. Loose-Fill Insulation

Loose-fill insulation materials are best used in non-standard or irregular joist and stud spaces, which are often found in older homes. The most inexpensive of insulation materials, they are often employed above flat ceilings. They can be poured or blown into awkward spaces and are often the only choice available when adding insulation to existing walls.

Loose-fill products are made of mineral or glass fibre, plastic, wood or paper products. *It is essential that paper or wood loose-fill insulation materials be treated for fire resistance.*

The RSI-values of these materials vary from 0.4 to 0.6 per 25mm of thickness (R 2.5 to 3.5 per inch).

C. Air-Vapor Barrier

Just as important as insulation in controlling heat loss is the air-vapor barrier. A polyethylene vapor barrier has been a standard part of construction for many years. Placed on the warm side of the insulation (the interior side), it prevents moist air from entering the insulation and condensing as it cools to form water or ice (Figure 9-2). Moisture in the wall cavity will destroy the insulation value and lead to structural deterioration of the wood as well. This vapor barrier, however, also functions as an air barrier—hence the name "air-vapor barrier."

There are many sources of moisture in a home. Cooking, bathing, showering, and laundering contribute humidity. People and pets release moisture through breathing. *As much as 10 kg (22 lb.) of water are added to the air in the average home every day.* High rates of air leakage in an older home easily remove this excess humidity. As a matter of fact, this high leakage rate results in most homes being dry in the winter. And, you will remember, this high rate of air leakage is also pumping a lot of heat out as well. Cutting down the leakage will save heat energy *and* retain some humidity.

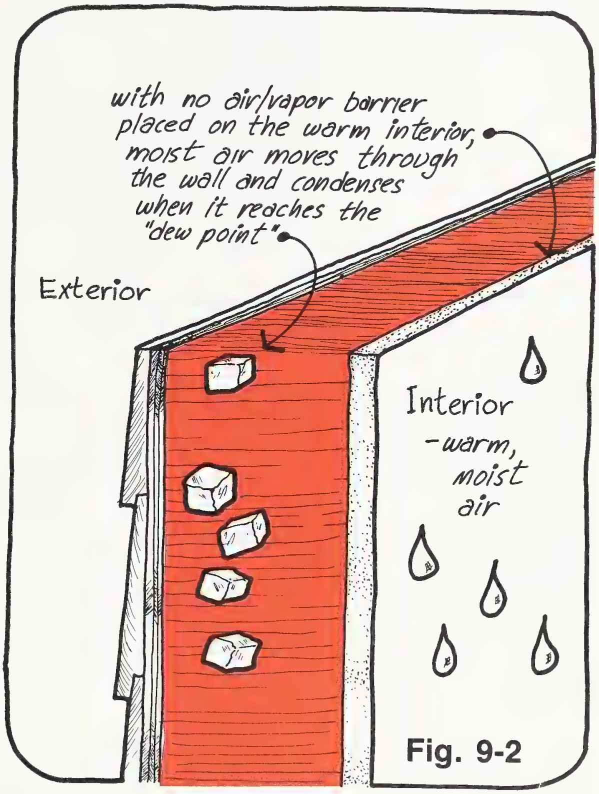


Fig. 9-2

Recent testing has shown that *severe* air leakage occurs past joints in the vapor barrier (assuming there is one), around punctures for vents, stacks, and electrical fixtures, through door and window rough openings, and around partition walls at ceiling and exterior wall joints. Leaving all potential air-leakage areas unsealed in the average existing home is like leaving a 600mm square (2') window open all year round. Using a heavier thickness of polyethylene when renovating and sealing it at all joints can control air leakage and heat loss. Applying caulking and weatherstripping to suspected leaks will also help (as described and illustrated in Program Eight). A good air-vapor barrier sealant is acoustical caulking or solvent-based acrylic caulking.

The air-vapor barrier does not have to placed right against the warm side of the wall. It can be located anywhere within the first one-third of the insulation value (measured from the warm side, as shown in Figure 9-3).

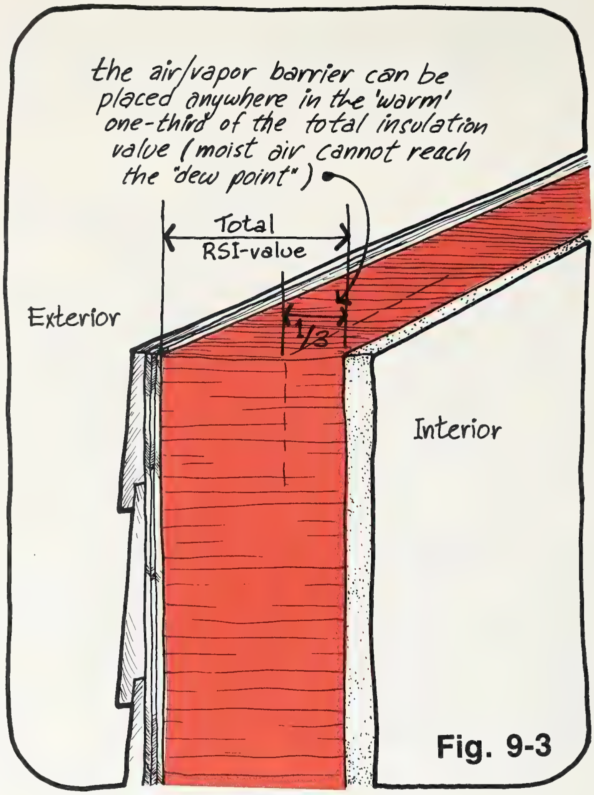


Fig. 9-3

D. Adding Insulation

1. Basements

If your home has an uninsulated basement, one-third of your total heat loss could be occurring through the floor and walls. The earth around the basement is *not* a good insulator, and the concrete or masonry itself conducts heat *out* of your house. Even if the basement space is only used for storage, heat from ducts and pipes, and from the main floor above, escapes readily through the uninsulated floor and walls and out through cracks, holes, or gaps in the joist spaces.

Besides lowering your total energy bill, insulating the foundation has other benefits. It adds to the habitable area of your home without the expense of adding on, and all areas of the home will be more comfortable and evenly heated if the basement is warmer. You can upgrade the basement walls with insulation added on the inside *or* on the outside.

a) Exterior Basement—Insulation Method

There are advantages to insulating your basement on the outside. Previously completed interior work is not disturbed, and all water lines are well protected against frost. There is no loss of interior living space due to thick walls. If there are cracks or leaks in the foundation wall, they can be repaired when the exterior is excavated. The foundation wall mass is contained inside the insulation layer, acts as thermal storage, and is not subject to wide temperature and moisture fluctuations.

The extensive digging required is one of the major disadvantages—especially for the homeowner doing the digging. This work has to be done in the warm season, and open excavations are subject to flooding during sudden rainstorms. And exterior insulation is difficult to apply if there are steps and decks attached to the house.

It is not absolutely necessary to excavate all the way down to the footing. An acceptable alternative involves carrying the wall insulation down to 300mm (12") below grade level, then laying a *horizontal* piece of insulation to control lower-wall heat losses. A typical foundation wall is shown in Figure 9-4, along with the area that has to be excavated. Care must be taken not to disturb utility connections when excavating around the foundation. *Check with the utility companies in question in case they have to come to the site and mark out where their connections are located.*

After digging around the foundation, the newly exposed areas must be cleaned and a new coat of waterproofing applied. The lower portion of the exterior wall finish should be removed at this time (Figure 9-5). The exterior insulation will then cover both the joist space and the foundation wall. If it is not possible to carry the insulation over the joist space, it should be insulated and sealed on the interior as shown in Figure 9-6.

The vertical portion of the wall insulation can be rigid polystyrene or rigid glass-fibre insulation (Figure 9-7). *The horizontal layer must be extruded polystyrene—a product that will not absorb moisture*. Flashing protects the top of the insulation from penetration by rain water, and pressure-treated plywood, stucco, or asbestos cement board protects the face of the rigid insulation from mechanical and sunlight damage. (Most rigid insulations degrade under ultraviolet light.) The insulation and wall protection can be attached using nails and adhesive. The horizontal portion of the insulation should be at least 200mm (8") deep under sidewalks and surface gardens or grass, and at least 450mm (18") deep under shrubs or flower gardens that are placed against a wall.

To control air leakage, the wall insulation must be well sealed. The joist space area should be sealed before insulation is applied (as shown in Figure 8-11, page 66). In addition, any ducts or pipes must be secured and sealed, and extended, if necessary, to reach through the wider wall. If the exterior insulation extends around any window openings, add flashing protection (Figure 9-8) and seal the joints well.

To complete the job, the excavation should be carefully backfilled. Avoid using large stones or lumps of clay since they may puncture the horizontal insulation layer. And make sure that the final surface slopes away from the wall for drainage purposes.

b) Interior Basement—Insulation Method

There are a number of advantages to insulating basement walls on the inside. Framing will provide a level wall surface to work on, and the interior design possibilities are limitless. The insulation work can be done in any weather, and no landscaping is disturbed. The wall framing provides a plumbing and wiring space, so that changes are easy to make when retrofitting. Further, the framing provides an ideal surface on which to install a complete air-vapor barrier. It is difficult, however, to seal the air-vapor barrier completely through the joist space.

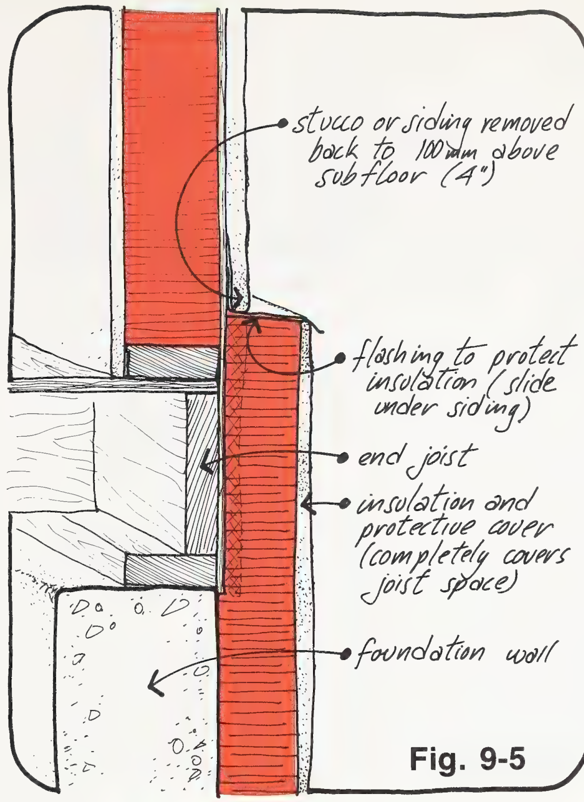


Fig. 9-5

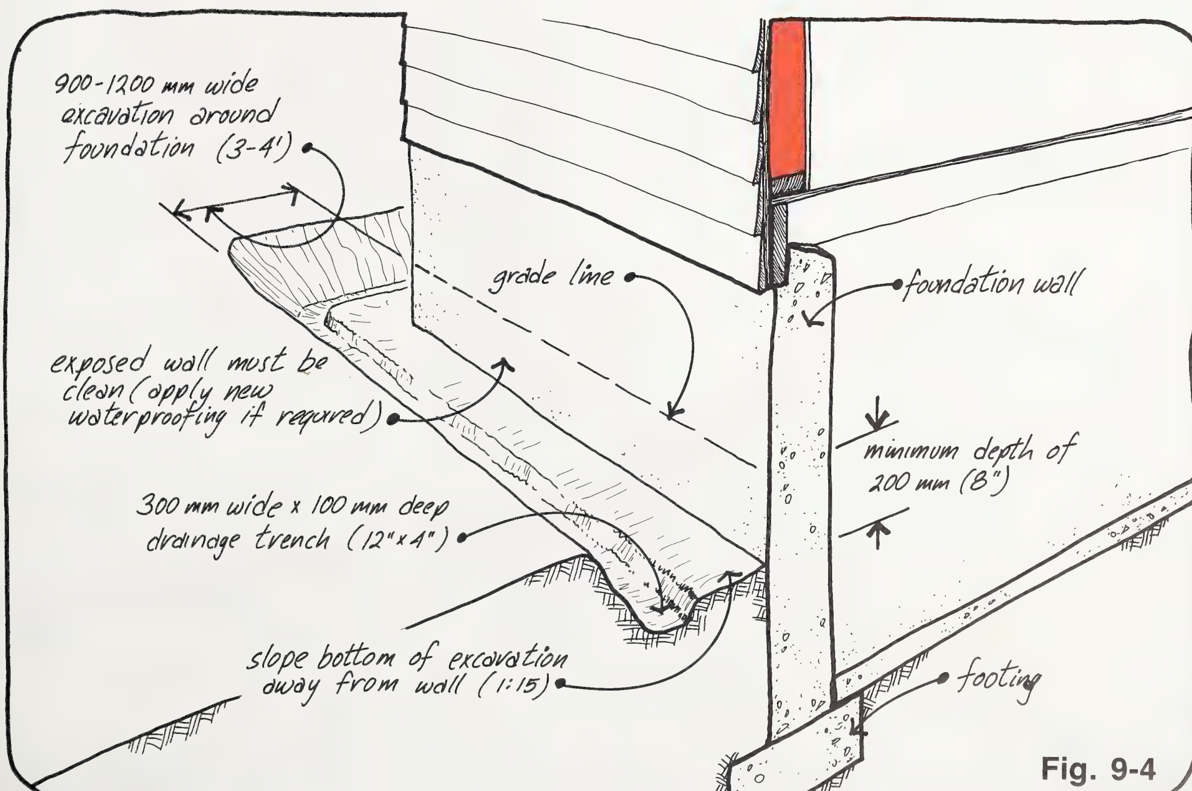


Fig. 9-4

There are other disadvantages to the interior method. Many older homes already have the basement interior completed, and removing existing work is expensive and wasteful. Retrofitting is difficult if there are a lot of pipes and ducts located against exterior walls, because these pipes and ducts *cannot be isolated outside the insulation layer*. If the foundation is subject to leakage from outside, then the interior cannot be covered until these moisture problems are solved (which may involve exterior excavation).

Before insulating the foundation walls, they, and the joist space, should be well sealed. As illustrated and explained in Program Eight, the importance of controlling air leakage should not be overlooked. Since interior insulation application will cover the wall and joist areas, *these points must be sealed first.*

The easiest method of interior insulation is to construct a frame wall against the foundation. This wall holds the insulation and wall finish in place. Before installation, however, a moisture barrier of heavy polyethylene (Figure 9-9) must be attached to the foundation wall from the grade level to the floor. This will keep any water that leaks through the wall out of the insulation. Since the barrier only extends from the grade level down, it will not trap moisture in the

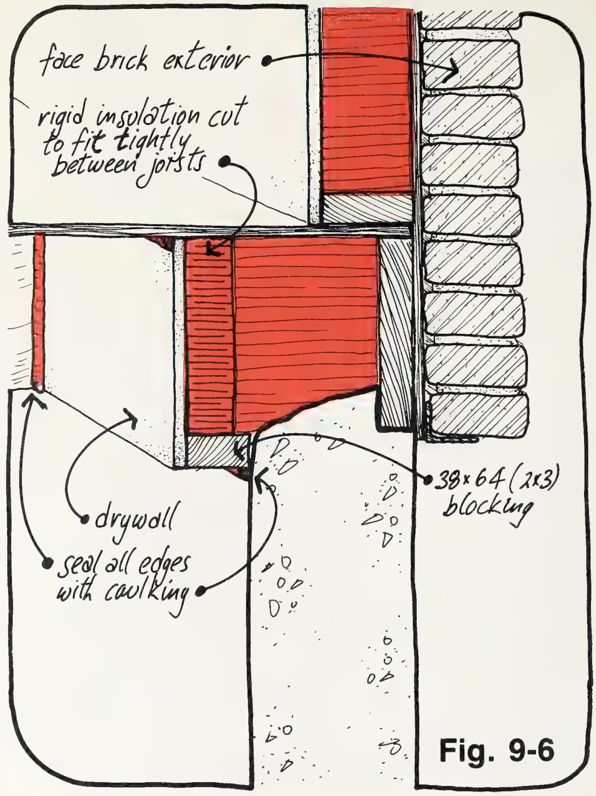


Fig. 9-6

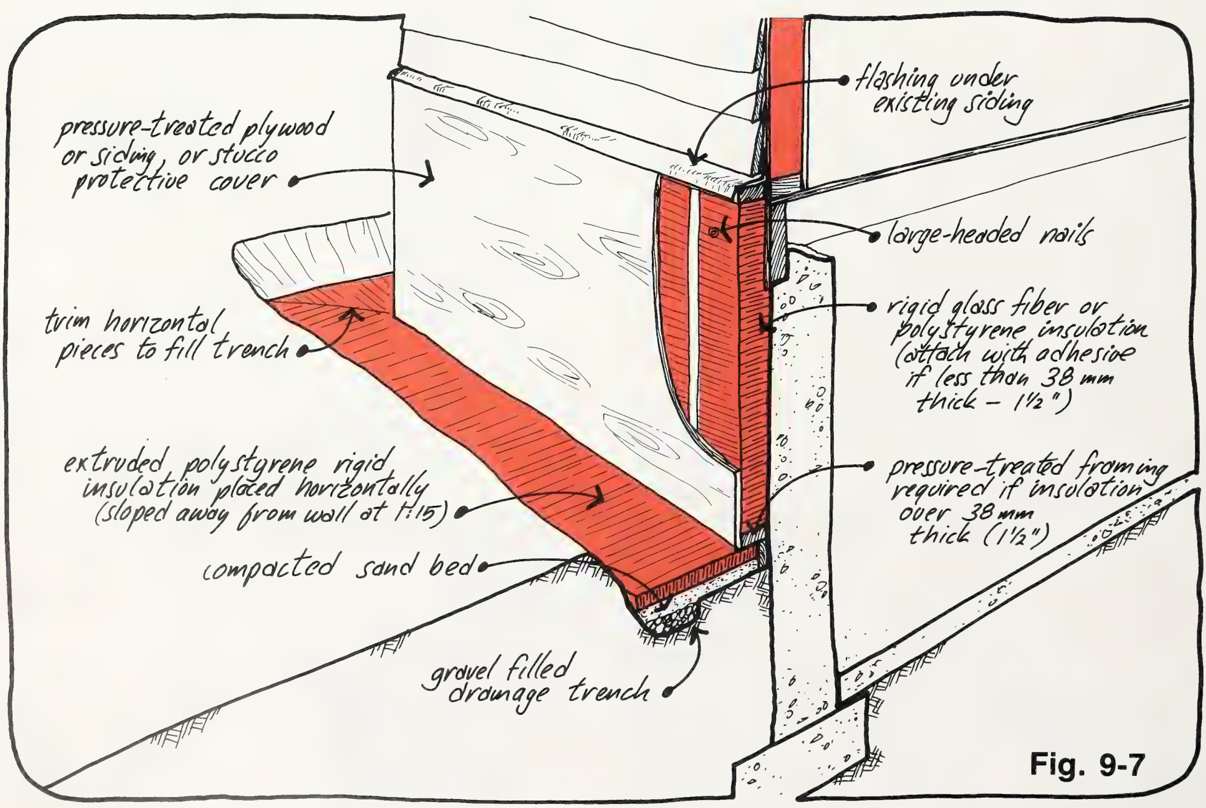


Fig. 9-7

insulation. (It is *not* the air-vapor barrier that is applied on the inside of the frame wall.)

The frame wall can be constructed from 38 × 89 members (2 × 4) on the floor and then raised into position. The interior face of the framing should be 150mm (6") in from the foundation wall (Figure 9-10) so that two layers of insulation are used—the outermost placed horizontally between the studs, the inner layer vertically. If there is any danger of moisture in the lower level, the bottom plate of the wall framing should be of pressure-treated material.

When framing, make sure that all water pipes and ducts remain *within* the insulated layer. This may involve moving some of them, or using thinner pieces of rigid insulation behind them. Electrical panels, gas or water meters may pose particular problems. Moving them requires service personnel and may be expensive. The simplest solution is often just insulating and framing as close as possible to the unit and using thinner insulation layers behind. Remember to cover any rigid plastic insulations used with drywall.

When the walls are framed, that's when any necessary electrical wiring changes should be done. Each switch, outlet, or junction box on an

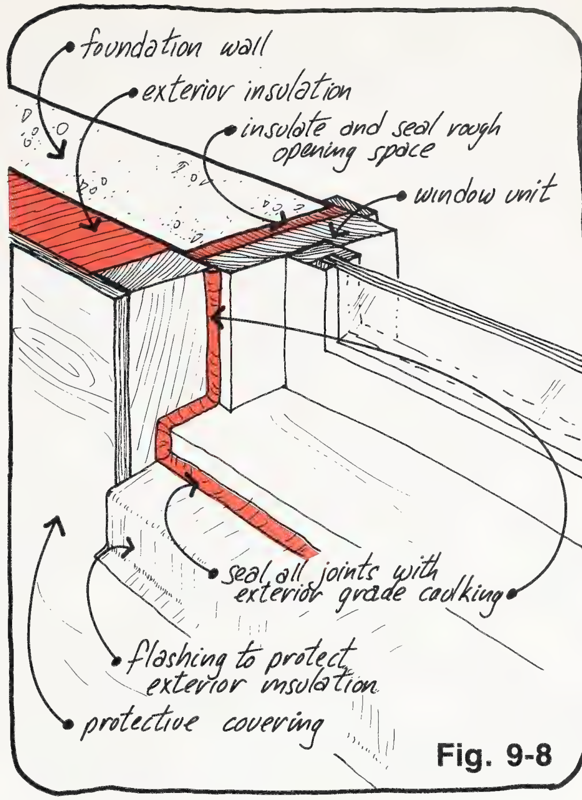


Fig. 9-8

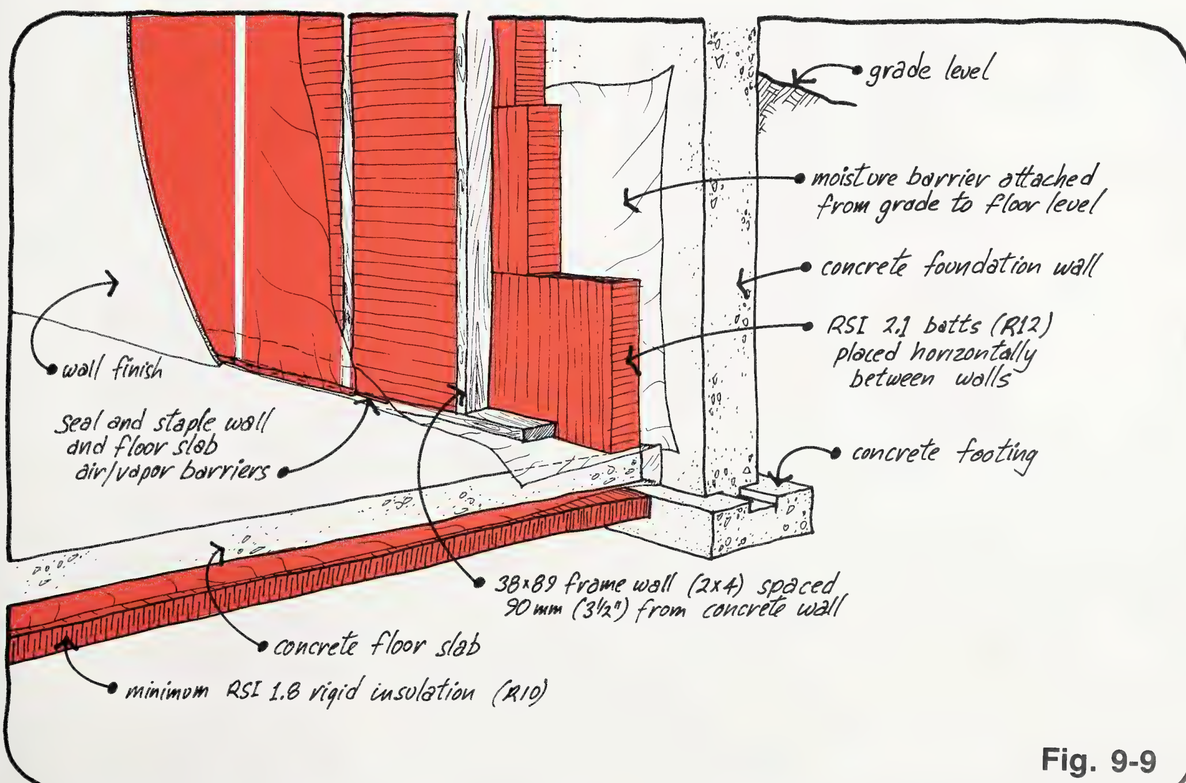


Fig. 9-9

exterior wall should have an air-vapor barrier installed behind it, using commercially available types (Figure 9-11). The framed walls can then be insulated. Be sure to fill the joist space and any floor overhangs under projections or bay windows (Figure 9-12).

After insulation, a complete air-vapor barrier can be applied. Any joints should occur over solid blocking and be sealed (Figure 9-13). Take particular care to seal the joist space area. This usually involves cutting blocks of rigid insulation to fit tightly between the joists, extending the air-vapor barrier to cover the blocks, then covering the area with wall finish (Figure 9-14).

There are no limitations to the type of wall covering or ceiling finish that can be used *unless rigid insulation has been applied. This product must be covered with plaster or drywall that is securely anchored to the foundation*. Suspended ceiling systems work well since access for future repair or extension work is convenient.

Remember that your foundation can account for a large percentage of the total heat loss from your home. Even if used only for storage purposes, the basement should be insulated to lower total home heat losses. If portions of the lower level are to remain unheated (for instance, a garage or cold storage area), then they must be insulated and sealed from the heated portion of the home. When isolating these spaces, *the air-vapor barrier goes on the* warm *side*. For example, when insulating the ceiling of an unheated garage in the basement, the air-vapor barrier goes directly under the subfloor (Figure 9-15). It is also important to insulate heating ducts or water pipes, which may be exposed to unnecessary heat loss in unheated areas. Commercially available duct and pipe insulations are available to help you accomplish this. All doors between heated and unheated spaces must be properly weatherstripped as well.

2. Attic Spaces

In the attic space of most existing homes there is usually some insulation on the "floor", the ceiling of the heated space below. The amount, however, is often marginal. By measuring the depth of the existing insulation, identifying it (which may involve taking a sample to a local building supply outlet) and finding out the RSI-value per 25mm (per inch), you can calculate the amount of insulation present. Adding more insulation can be a fairly easy job in some attics with lots of space; in others, with little headroom or lots of obstructions, this will not be simple. As with any retrofitting task, however, the air leaks

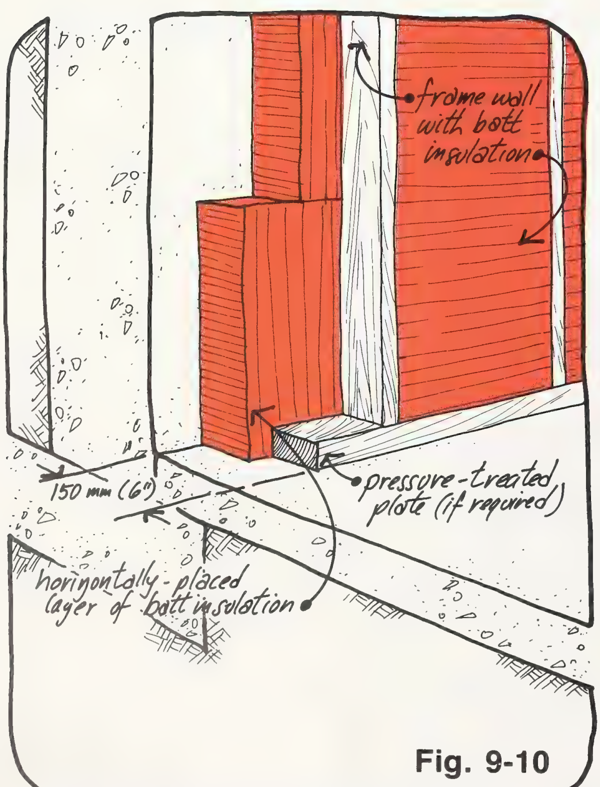


Fig. 9-10

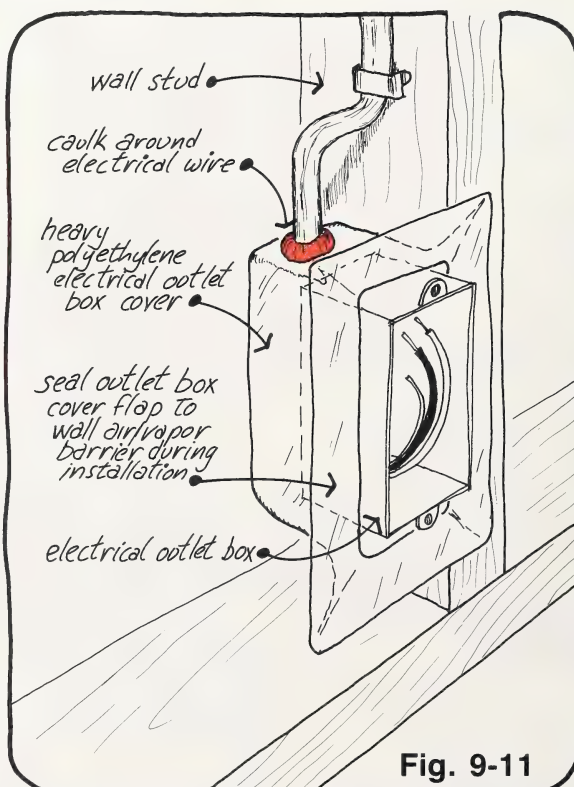


Fig. 9-11

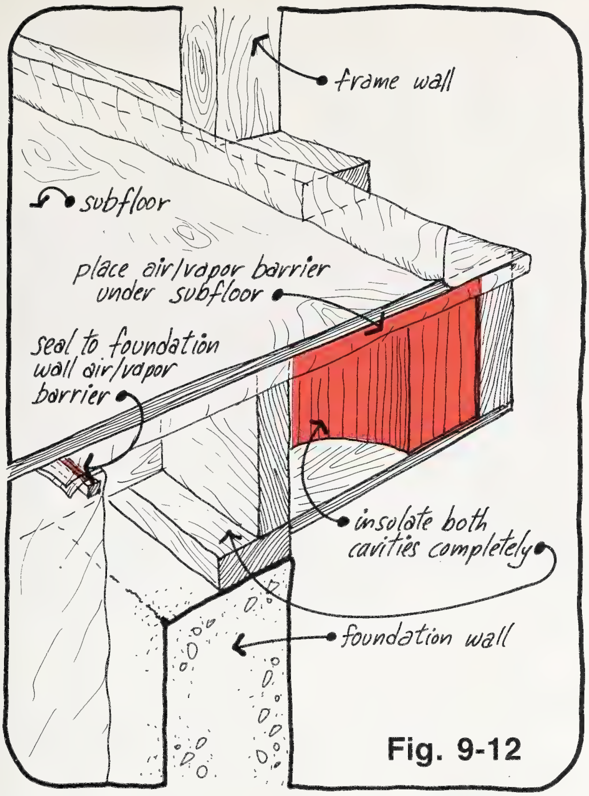


Fig. 9-12

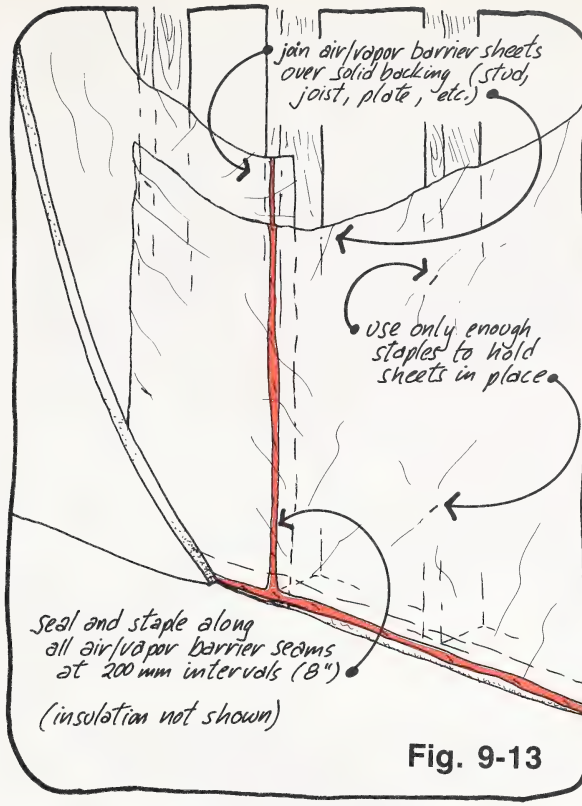


Fig. 9-13

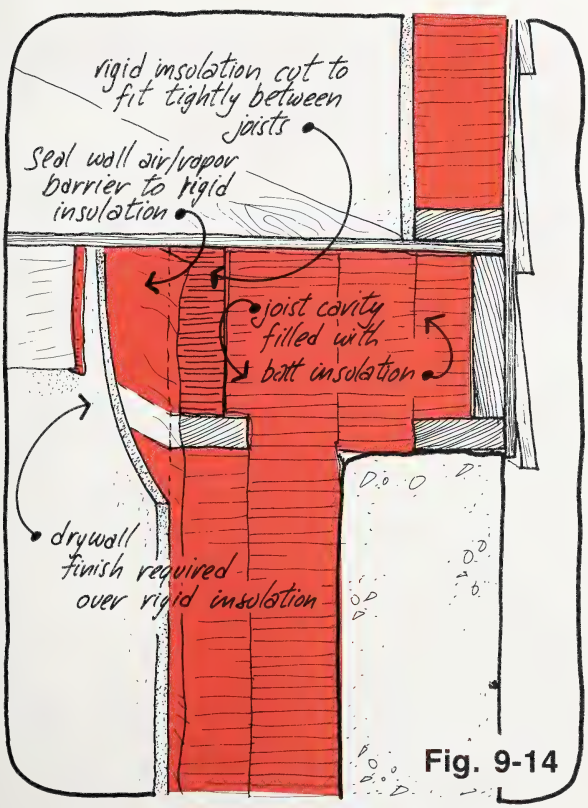


Fig. 9-14

in the ceiling surface must first be plugged. The information and illustrations in this program cover flat ceilings under standard attic spaces. Sloping ceilings and kneewall spaces are dealt with more completely in Program Ten.

a) Plugging Ceiling Air Leaks

A problem that often occurs in older homes is the complete absence of an air-vapor barrier. If this is the case, there are a number of ways to add one to the existing ceiling.

If the attic has little insulation, this can easily be removed to expose the ceiling for the application of an air-vapor barrier from above. A continuous sheet of heavy polyethylene is placed over the existing ceiling surface (Figure 9-16) and allowed to drop down between each joist space. Insulation is then added on top *to a depth of at least three times the joist depth* (in order to place the air-vapor barrier in the warmest one-third of the insulation layer). This method is most convenient if there are few obstructions in the attic area. If there are many, e.g., supports or trusses, then individual sections of polyethylene can be cut and sealed into the individual joist spaces (Figure 9-17). Insulation is added after this job has been completed.

In many attics, there is a layer of existing insulation as deep as the ceiling joists. In this case, it is possible to place an air-vapor barrier over the insulation layer, seal it around the edges and to any pipes or ducts, and then cover it with insulation *to a value at least double the original layer* (Figure 9-18). For example, if the existing ceiling insulation has an RSI-value of 2 (R 11), then an insulation depth with a resistance of RSI 4 (R 23) can be added after the air-vapor barrier is in place. This ensures that the barrier is within the warmest one-third of the total insulation value.

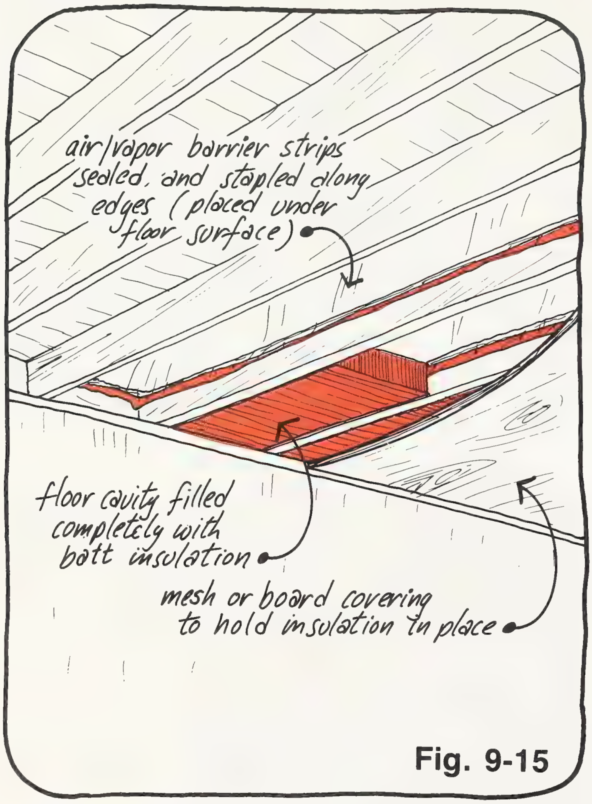


Fig. 9-15

There are two methods of applying an air-vapor barrier to the underside of an existing ceiling. One way is to *paint* the surface with a good quality oil-based paint or a specially formulated latex vapor-barrier paint. The second involves covering the ceiling with a heavy polyethylene sheet on the underside, sealing the edges, then applying a new covering of wall board over the surface. This is a good technique if the ceiling surface is in poor condition and needs redoing.

Even if an existing attic has an air-vapor barrier, there will be a number of individual sources of air leakage. (Information regarding sealing around chimneys and stacks is illustrated in Figures 8-13, 8-14, and 8-15.) Electrical ceiling

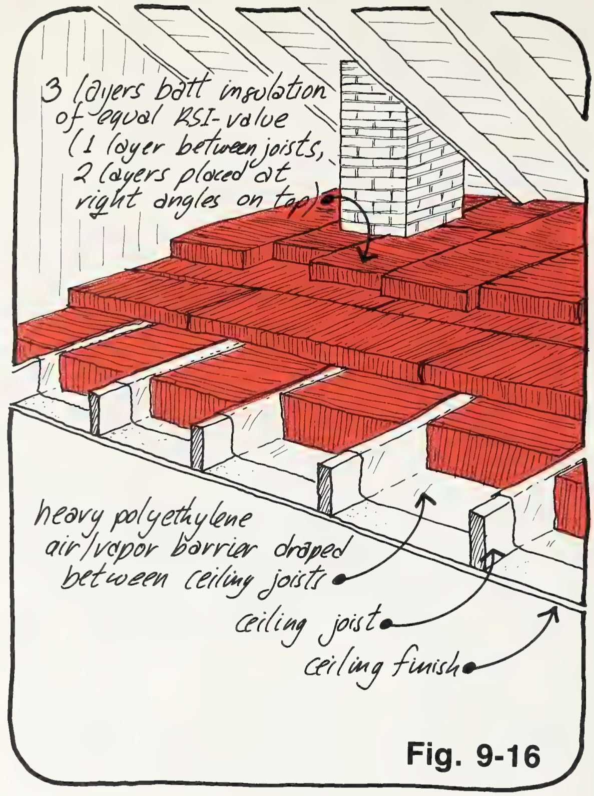


Fig. 9-16

fixtures and junctions boxes can also be sources of air leakage. These can be plugged by sealing a square of heavy polyethylene over them to the existing air-vapor barrier (Figure 9-19).

There are often gaps in the ceiling air-vapor barrier along interior partition walls. These cracks can usually be easily exposed by moving away the insulation, cleaning out the gap, and sealing by running a bead of caulking along the joint. But, in addition, *take care to seal around any wires passing through the ceiling* (Figure 9-20).

As described and illustrated on page 64 (Figure 8-7), the attic access hatch must be well-insulated and weatherstripped to cut down heat loss. If you are considering extensive renovations to the exterior, the attic hatch can be moved to a gable end (Figure 9-21). This will eliminate one "exterior" door in the home, and access is just as convenient from the exterior as from a closet in a hallway.

b) Attic Ventilation

Adequate ventilation is required in the attic space to protect against moisture accumulation. You must provide $0.33 m^2$ of free ventilation area for each $100 m^2$ of ceiling area (one square foot for each 300 $ft.^2$). This can be provided with a combination of soffit vents, roof vents, ridge

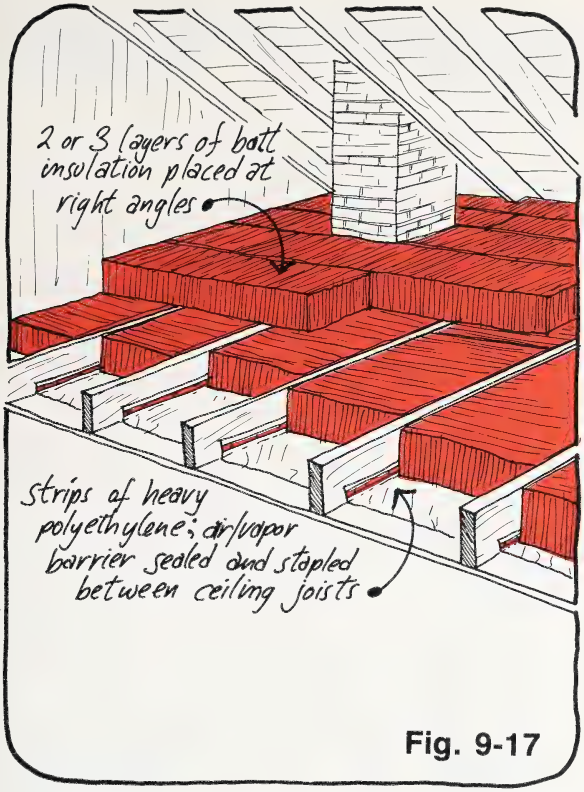


Fig. 9-17

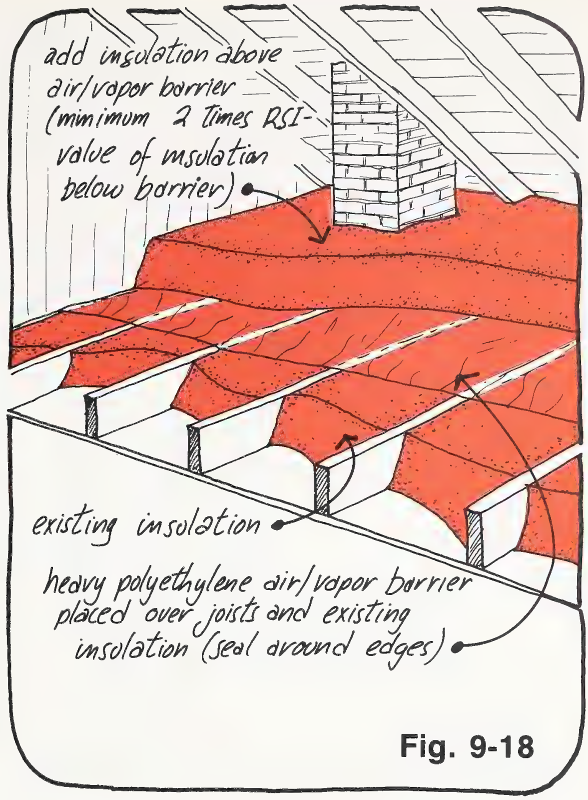


Fig. 9-18

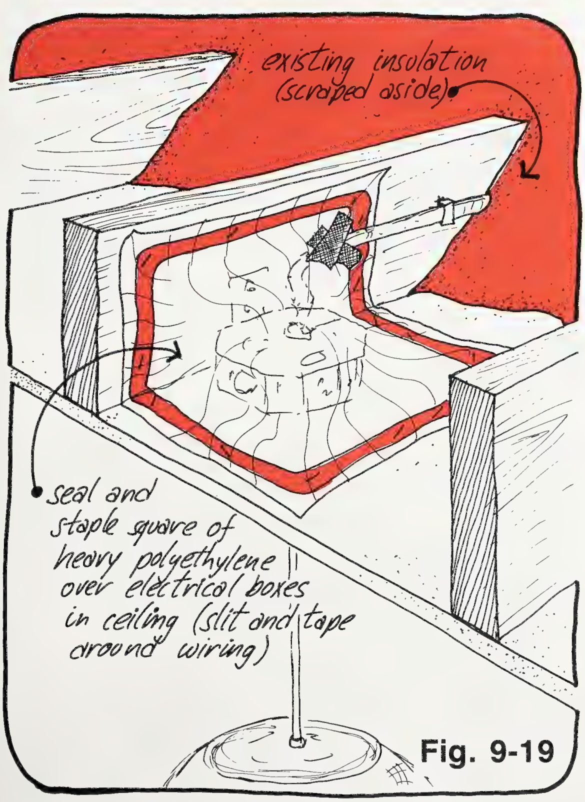


Fig. 9-19

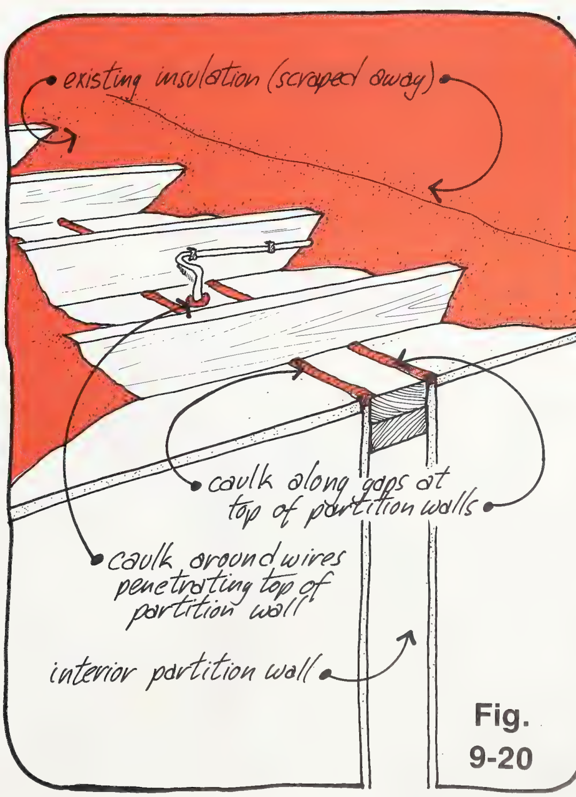


Fig. 9-20

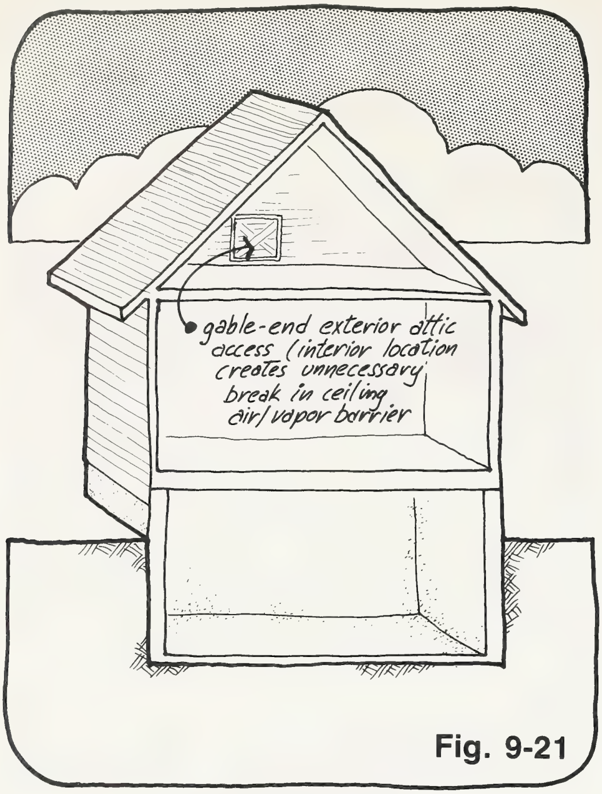


Fig. 9-21

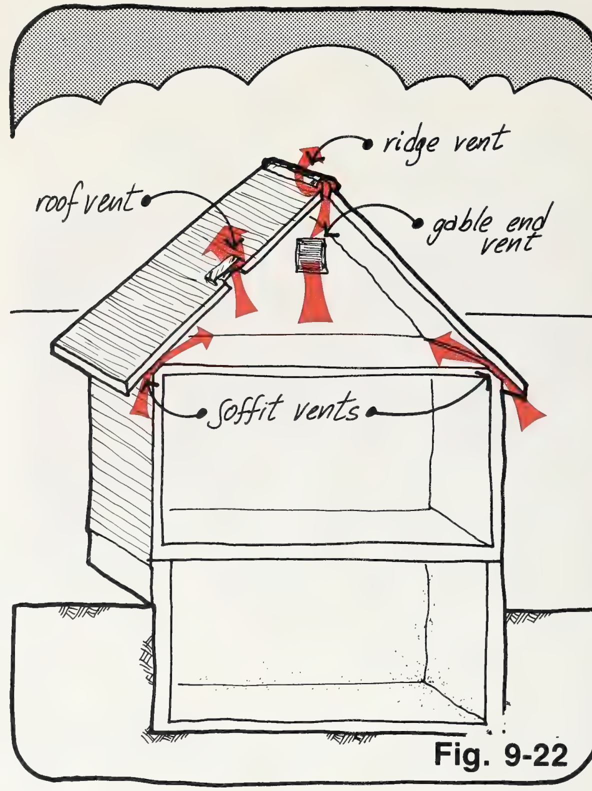


Fig. 9-22

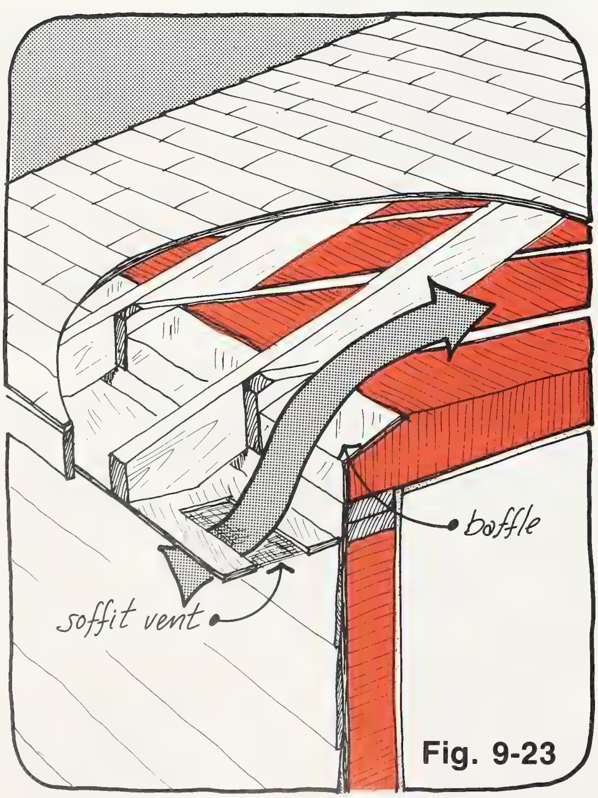


Fig. 9-23

vents, or gable vents (Figure 9-22). Venting keeps the attic space cooler in the summer and allows any condensed moisture to transpire out before ice is formed in the winter.

If the attic space is lacking in ventilation, adding more insulation can cause problems. The space will now be cooler in the winter (due to less heat loss), and ice may form in areas previously ice-free—especially if any air leaks have not been sealed. Check the total ventilation area and add more venting if required. Roof and gable vents are the most convenient to install. Soffit vents can be added as well, although many older homes may not have soffits.

Any vents that are located in, or are added to, the soffit area must be protected with baffles or insulation stops. These baffles (Figure 9-23) will keep insulation from blocking free passage of air into the attic. They can be made of plywood or waxed cardboard. Manufactured units are available to fit various rafter spacings.

c) Attic Insulation

The installation method and type of insulation used to add attic insulation depend on a number of factors. Space available, homeowner expertise, budget, existing insulation, and roof construction are the main ones.

Batt or blanket insulation is the easiest for the homeowner to apply. Two or three layers should be installed at right angles to each other to form a tight, complete layer (Figures 9-16, 9-17). Accurate cuts should be made around any supports, pipes, or irregularities. Construct drywall boxes to keep the insulation away from any recessed light fixtures (Figure 9-24). Be sure to cover the boxes with a well-sealed air-vapor barrier. Further, exhaust fan ducts must be sealed and covered with insulation.

For attic spaces with very limited access or lots of obstructions, commercially applied, blown-in insulations are the most economical to use. Again, be certain that air leaks are well-sealed, that insulation stops are used to protect ventilation, that the access hatch is insulated and sealed, and that a uniform depth of insulation is installed. (Check the depth after a few weeks to see that it has not settled below the amount agreed upon with the contractor.)

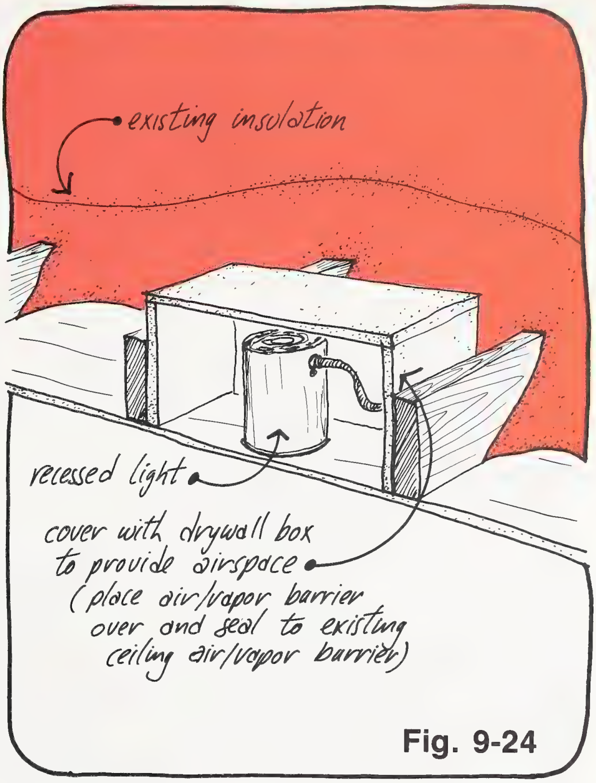


Fig. 9-24

Summary

Insulation and an air-vapor barrier work together to cut down heat losses. In retrofitting, the first priority is to insulate and seal any uninsulated areas. In many existing homes, this is often the foundation. In addition, attic spaces have little insulation and many air leaks in most cases. Sealing the leaks and adding some insulation will not only lower heat losses but also eliminate the potential for condensation damage.

Doing a good job of retrofitting in the basement and attic will go a long way toward eliminating a large part of that 40% of total heat loss. Many aspects of the techniques illustrated are inexpensive and easy for the homeowner to undertake. And the economic benefits will become obvious within a very short time.

EXISTING HOMES: WALLS AND WINDOWS

OUTLINE

In this program, details are given about the upgrading of walls and windows. This includes the creation of useable spaces in second-level areas: the kneewalls, floors, and sloping ceilings often found there.

Although attics and foundations account for the largest portion of heat loss, cutting down drafts and adding some insulation to walls that have not been insulated will improve the comfort level. The benefits to your family of a more comfortable living space often outweigh the energy savings resulting from this aspect of retrofitting.

A. Transmission Heat Loss

The transfer of heat through any material occurs in large part by conduction. The rate of heat flow depends on the material's thermal resistance (R-value or RSI-value) and on the temperature difference between one side of the material and the other. The greater the temperature difference between the inside of a house and the outside, the "faster" heat flows through the walls, floors, doors, windows, and ceilings. (The formula to calculate heat flow is shown on page 56.)

Higher levels of insulation will slow down the heat flow but not stop it completely—as long as there is a temperature difference between inside and outside. High insulation levels will also slow heat flow from outside to inside on summer days. The levels of insulation you should try to attain when retrofitting are illustrated in Figure 9-1 (page 68). Also included in that section is a description of various insulation products.

Just as important in controlling heat loss is the air-vapor barrier. As explained and illustrated in Program Nine, it acts in conjunction with the insulation layer to lower home heat losses.

B. Adding Insulation

The second level of many older homes resembles the cross-section shown in Figure 10-1. Space behind the kneewalls is often used for storage, the tiny attic area is difficult to add insulation to, and the sloping parts of the ceiling offer little joist space for higher insulation levels. The actual "attic space" may be poorly insulated—if at all—yet this potential extra area appeals to a family with an otherwise full house.

1. Kneewall Spaces

Increasing the insulation value of the spaces behind kneewalls is often the easiest part of dealing with the house shapes that contain them. Access doors are usually available, but, if not, a hole can be cut into the wall. If the "floor" of the storage area has a covering, remove it to check the insulation and air-vapor barrier. (Remember that this is the ceiling of the heated area below.) If no air-vapor barrier is present, one can be added to both the floor and the kneewall, using techniques described in Figures 9-16 and 9-17.

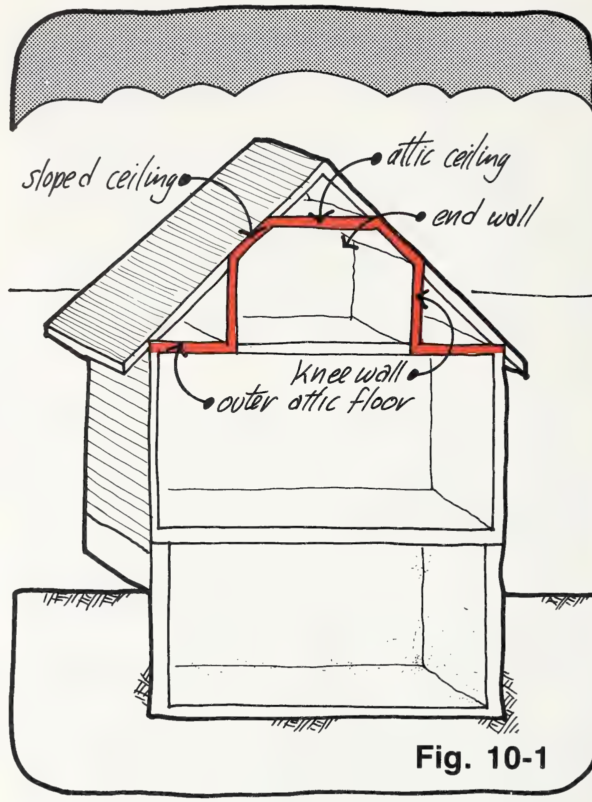


Fig. 10-1

Be sure to seal over any electrical outlet boxes, around any stacks or chimneys, and along any wall plates, using the techniques illustrated in Figures 8-12, 8-13, 8-14, 8-15, 9-19, and 9-20. Batt insulation can be added to both walls and floor. You should try to attain an RSI-value of 3.5 (R 20) on the walls and an RSI-value of 7 (R 40) on the floor of the storage space. Insulate and seal the access doors to the kneewall space when all the work is completed.

While inspecting kneewall spaces, measure the ventilation area. If less than the 1:300 ratio of vent area to floor area, add ventilation in the form of gable end or roof vents (Figure 10-2).

2. Sloped Ceilings

Any ceiling with little or no space between it and the roof structure must either be insulated below the ceiling surface or above the roof layer. The problem of where to add insulation to this type of

ceiling occurs with open-beam (or cathedral) structures, as well as in the attic of a two-storey building.

a) Interior-Strapping Method

One of the easiest methods of adding insulation to an existing sloped ceiling is to strap it on the inside and add insulation between the strapping (Figure 10-3). Two layers, with the strapping in one running perpendicular to the other, will create one well-insulated layer. A complete, well-sealed air-vapor barrier can be installed over the new insulation prior to applying the ceiling finish. Using rigid types of insulation enables you to attain the highest insulation value with the least possible thickness.

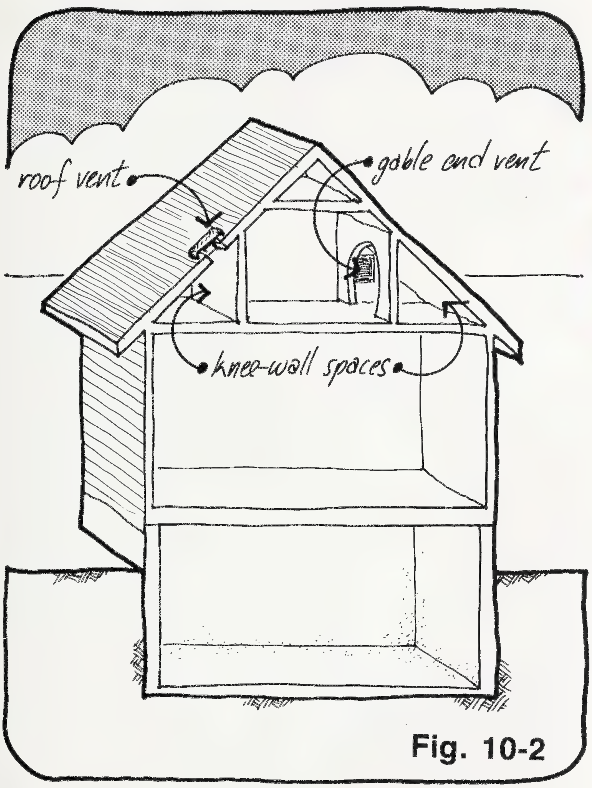


Fig. 10-2

b) Exterior-Insulation Method

A sloping ceiling is often a feature in a home, and the occupants may not want to cover it with layers of insulation. In this case, a new roof can be added over the existing one to hold more layers of insulation. The existing shingle layer is removed, a new air-vapor barrier placed on the surface, and then strapping installed to contain the insulation. A new sheathing layer is placed on top, new shingles being added afterwards. As illustrated in Figure 10-4, this technique can be used to add a very high level of insulation. At least twice as much material can be added *above* the new air-vapor barrier as exists below it—so that the barrier is within the warm one-third of total insulation layer. (The major retrofit example illustrated later in this program gives more details regarding extra roof insulation.)

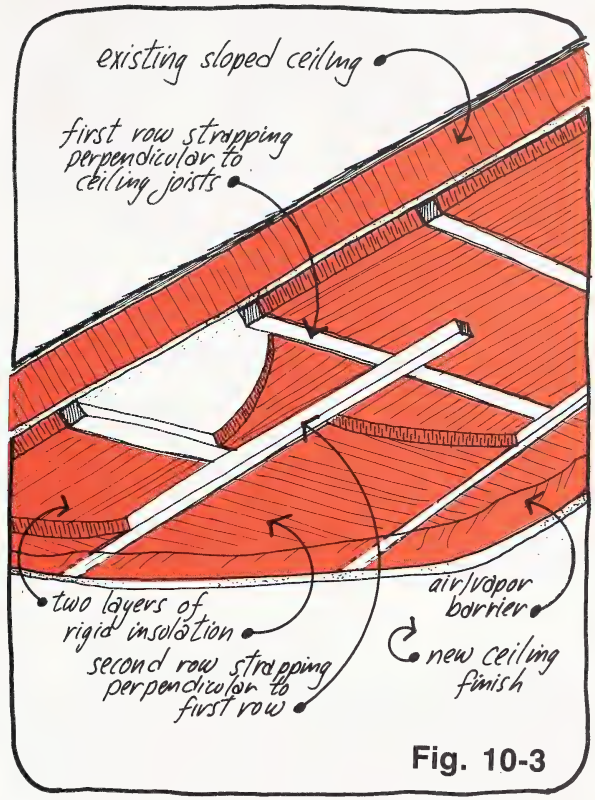


Fig. 10-3

3. Walls

Adding insulation to existing walls can be very difficult if you do not want to remove existing finishes, exterior or interior. If either of these finishes is due to be replaced, then options other than blowing or pouring insulation into the wall cavity are feasible.

a) Filling Wall Cavities

Loose-fill types of insulation, which can be blown or poured into wall cavities, include cellulose fibre and vermiculite. *Adding insulation to a wall cavity by blowing or pouring can only be done if there is* **no** *insulation present.* And the procedure is difficult because wires, firestops, and lintels block portions of the wall, making a complete insulation job difficult.

Most homes lacking insulation in the walls will not have an adequate air-vapor barrier. Installing one is a major task that is better done in conjunction with adding insulation to the inside

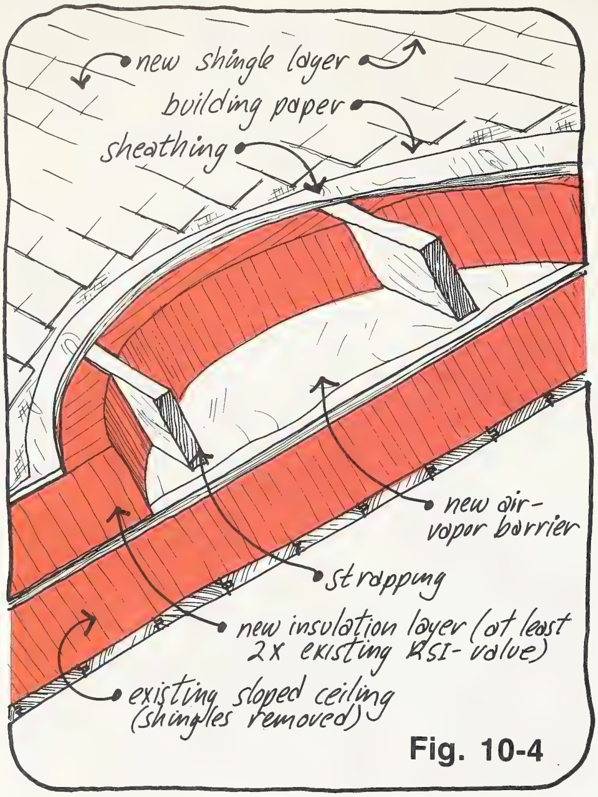


Fig. 10-4

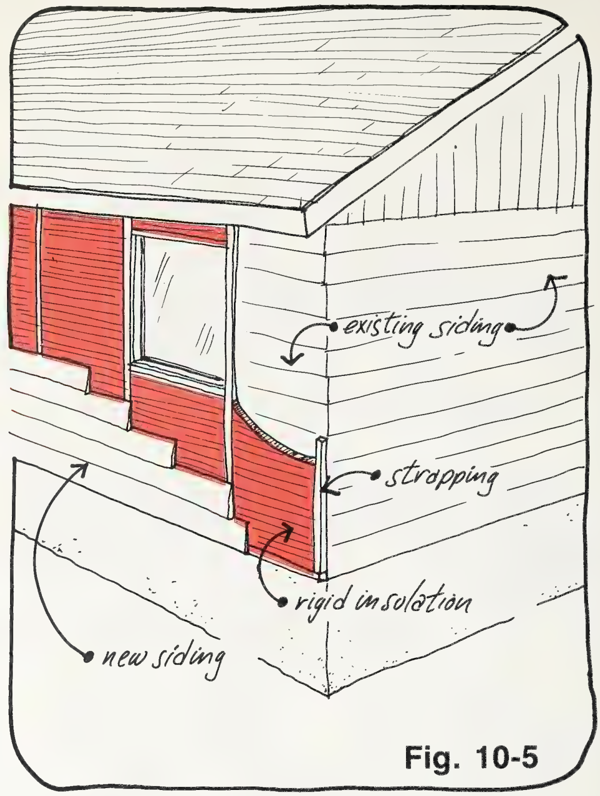


Fig. 10-5

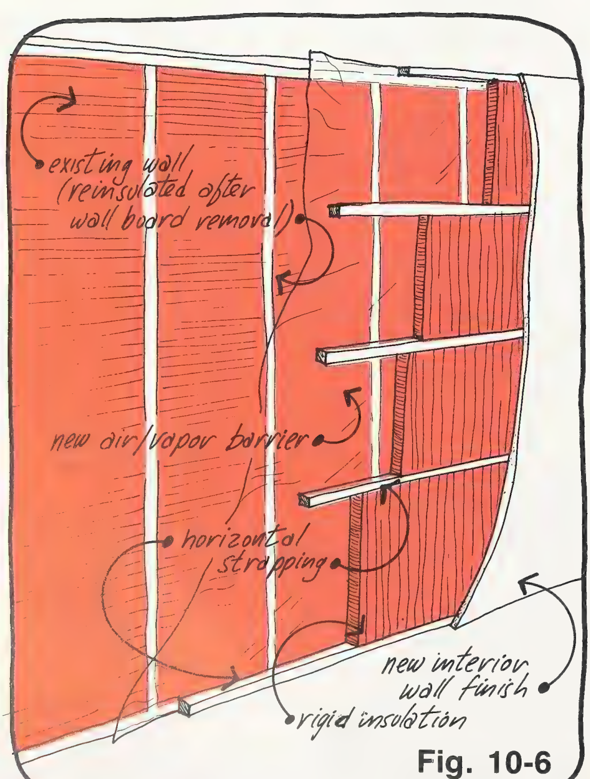


Fig. 10-6

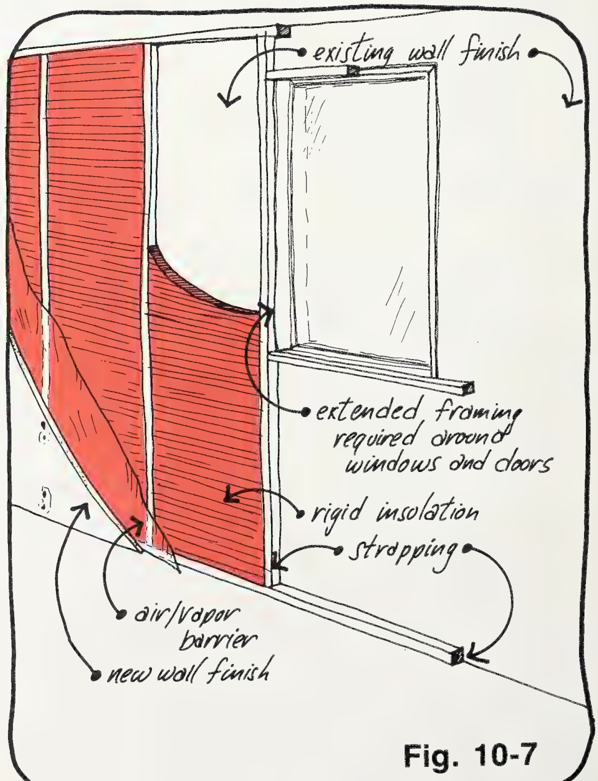


Fig. 10-7

or to the outside of the existing exterior walls. The best method is illustrated in Section C, Major Exterior Retrofit, which follows.

b) Exterior-Wall Insulation

Adding insulation to the outside of existing walls is a logical step if the homeowner is considering a new exterior finishing material. Rigid insulation materials can be installed over the existing siding (Figure 10-5), and then a new finish applied on top. This involves using strapping to hold the insulation and extending window and door casings to the thickness of the new walls. Because of the expense involved, this method of upgrading wall insulation is justified only when renovations are being contemplated in any case—dollar savings from lowered heating bills will not pay off the expenditure involved.

c) Interior-Wall Insulation

Exterior retrofits, although convenient because there is not disruption to the house interior, are not always practical. They are costly, the existing exterior may well be in good shape, the exterior may be a structural part of the home, or there may be a finish such as brick, which the homeowner does not want to cover up. If you are considering interior renovations, adding insulation on the inside could be quite convenient. It can be done in conjunction with new wall finishes, window placement changes, or interior space rearrangements.

If renovations involve rebuilding the exterior wall finishes, then new insulation can be added, rewiring done, and a new air-vapor barrier installed. An even better solution is to re-insulate the existing wall, attach the air-vapor barrier, then strap the interior with 38 × 38 boards (2 × 2's). The strapped space (Figure 10-6) can have RSI 1.2 (R 7) insulation installed before the drywall is added. A total RSI-value of 3.7 (R 21) in the wall will provide good heat-loss protection, a new air-vapor barrier will minimize air leakage, and the barrier is located within the warmest one-third of the insulation. Isolating the air-vapor barrier in the wall, as shown, protects it from mechanical damage when the wall finish is installed.

It is also possible to construct a new wall inside existing exterior walls. (This may be the only solution if the existing walls are masonry.) A new air-vapor barrier can be installed on the inside after strapping and insulation have been accomplished (Figure 10-7). Whenever the wall is thickened on the interior, the window and door casings have to be widened. If this type of retrofit is contemplated, make sure no water lines are isolated to the exterior.

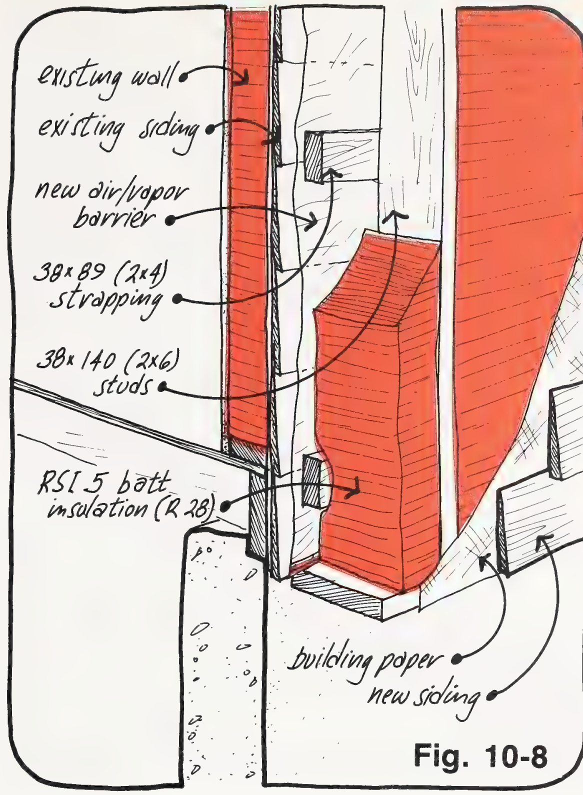


Fig. 10-8

C. Major Exterior Retrofit

In the case of homes that have low levels of insulation, lack an air-vapor barrier, and are fitted with poor-quality windows and doors, a technique has been devised to carry out a simple exterior retrofit that solves all these problems. The initial phase of this renovation involves totally covering the structure in heavy polyethylene. Since this places the air-vapor barrier on the outside, new walls and a roof cavity are constructed to hold high levels of insulation. The polyethylene is initially held in place with strapping.

The wall construction method is shown in Figure 10-8. Wall strapping of 38 × 89 (2 × 4) holds the air-vapor and provides support for the vertical 38 × 140 (2 × 6) members. Sheathing, building paper, and siding completes the wall construction. The wall cavity created holds an RSI-value of 5 (R 28) outside the air-vapor barrier. As long as the initial wall has an RSI-value of no more than 2.5 (R14), the barrier is within the warm one-third of the total. Most existing older homes only have an RSI-value of 2 (R 11) or less in the walls.

Figure 10-9 shows the roof construction method. Again, strapping holds the air-vapor barrier in

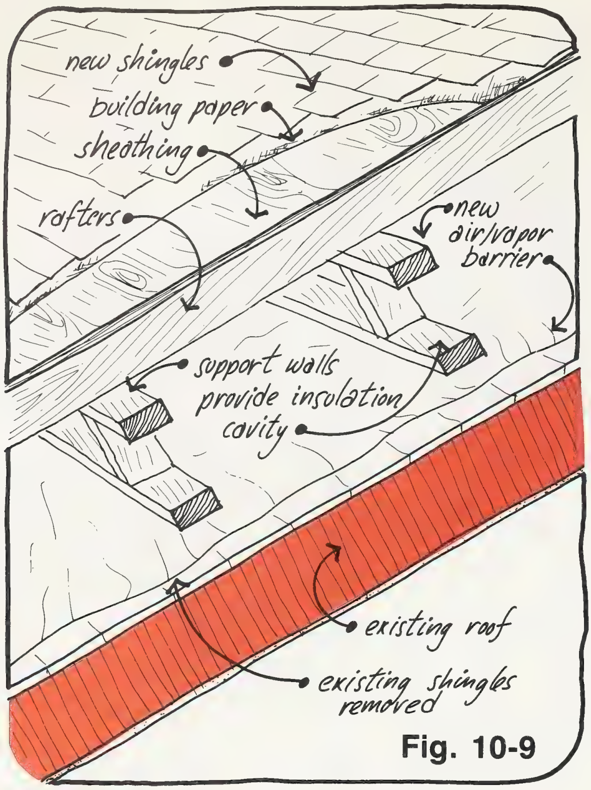


Fig. 10-9

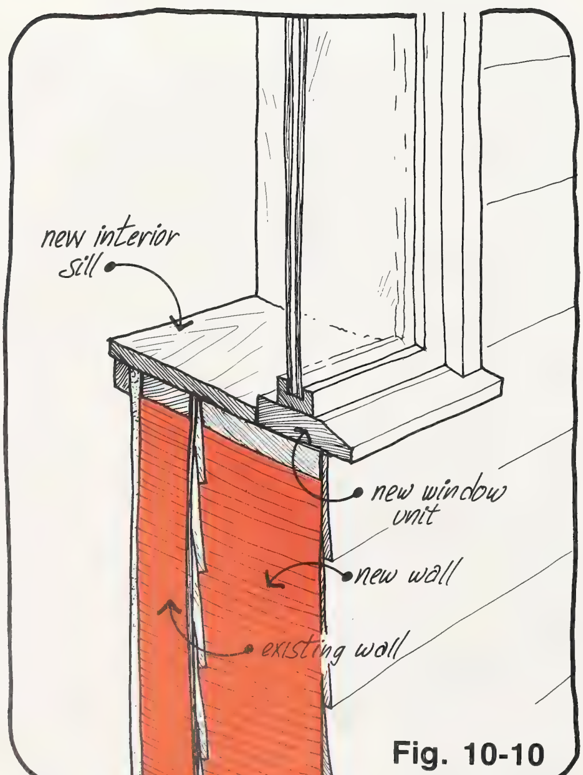


Fig. 10-10

place. Short support walls—or wide joist members—hold a new set of rafters and create the insulation cavity. By varying the height of the support walls, it is easy to build a cavity capable of holding RSI 7 to 9 (R 40 to 50) above the air-vapor barrier level. This solution works well for homes with lots of irregularities in their construction such as dormers and attic spaces. The polyethylene layer continuously covers the whole structure—irregularities and all.

If new window units are installed, the detail shown in Figure 10-10 provides an idea for placement. Locating the new units on the exterior will create wide sills—handy for plants. Placing the units on the interior will create an air pocket on the exterior and shield the windows from winter winds. In addition, warm air from the forced air ducts will keep condensation on the window surfaces to a minimum during cold winter nights.

D. Windows

Windows are sources of heat loss by conduction. No window is a good insulator but, of course, is necessary as a source of light, ventilation, and viewing. Although windows are great passive solar-collection devices when oriented properly, at night they become uninsulated "holes" in your home. Even double-glazed windows only have an RSI-value of 0.30 (R 1.8)—less than one-tenth the value of a typical wall in an upgraded home.

Insulated windows rely on the air between the panes for their resistance value. To be effective, air space must be at least 12mm (1/2") thick. Adding a third layer of glass or plastic to create a triple-glazed unit gives the window an RSI-value of 0.46 (R 2.7)—50% better than double glazing but still far below the value of a wall or ceiling. More layers become expensive as well as cutting down on the solar energy allowed through. (Each pane decreases light transmission by about 10%.)

Movable-window insulation can reduce heat loss during the night or in sunless winter periods. It can also function as a window cover, taking the place of a drape, and will make interior spaces more comfortable in cold weather. To be cost effective, however, window insulation must be used *consistently* throughout the heating season. This insulation must also be *convenient* so that using it does not become a chore.

There are various types of interior window-insulation systems which the homeowner can easily add. These include drapes, blinds, shades, and shutters. Drapes or rolling blinds are difficult to construct thick enough for very high insulation levels and are difficult to seal. *To be cost*

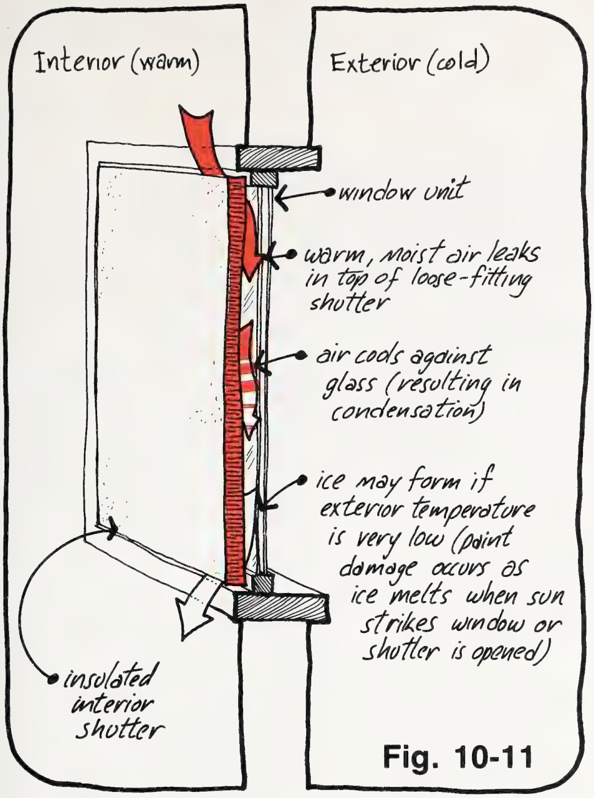


Fig. 10-11

effective, window insulation should have an RSI-value of 1.0 (R 5.7). Any insulation mounted on the interior must fit very tightly to prevent air movement. As shown in Figure 10-11, if warm moist air can leak past the insulated cover, it will condense on the cold window surface. When the insulation is removed in the morning, water damage occurs as the ice melts.

Numerous commercial products are available as drapes, shades, and blinds. Shutters can be individual panels (constructed by the do-it-yourselfer) that are installed at night and stored during the day, or they can be hinged or sliding units as shown in Figure 10-12. Window insulations can be custom-made. But when making your choice, consider cost, ease of use,storage, appearance, and combustibility.

Exterior shutter systems have some advantages over interior window-insulation units. Sealing them against air leakage is not as critical since condensation will not occur on the outside of the glass. Exterior shutters are better at preventing summer overheating, and their combustability is not a worrisome problem. However, operating exterior shutters can be a problem. Any pulley or arm system operated from the inside can break the air-vapor barrier and may lead to air leakage. And operating the shutters from the outside is

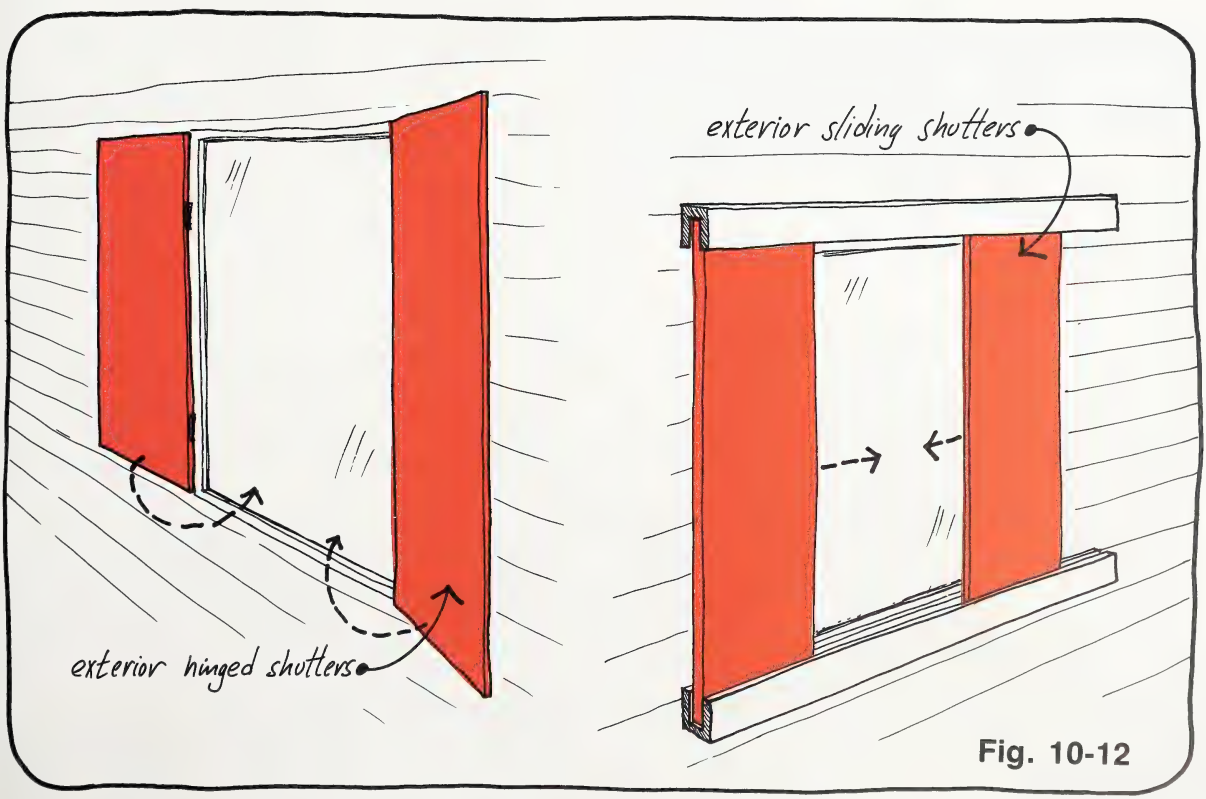


Fig. 10-12

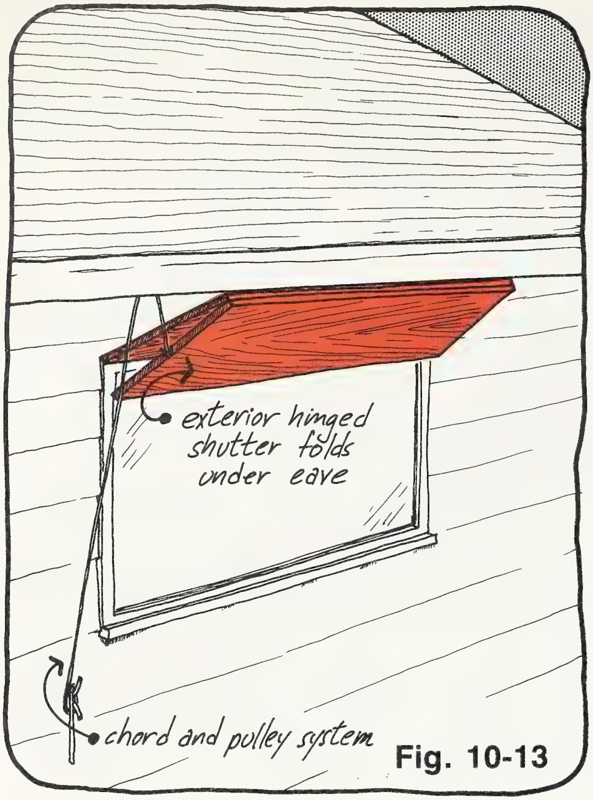


Fig. 10-13

definitely an inconvenience (Figure 10-13). Incidentally, the shutters should fit under the eave so that snow build-up is not a problem.

Summary

A complete insulation layer and a well-sealed air-vapor barrier work together to reduce losses drastically. When you retrofit, apply the principles of increased insulation and attempt to seal as many air leaks as possible as each assembly is upgraded.

Just as important as upgrading the basement and attic is the need to attend to the walls and their openings (windows and doors). Adding insulation to and sealing *all* sources of air leakage may seem impossible at times, but there are as many solutions as there are types of different homes. Perseverence in doing a good job will pay off in lowered energy bills.

EXISTING HOMES: HEATING ALTERNATIVES

OUTLINE

Retrofitting your home to reduce heat-energy demand can have a dramatic effect on the heating system. Increasing insulation levels and sealing air leaks results in less heat escaping outdoors. This program provides information on heat-fuel options and heat-distribution systems. The advantages and disadvantages of fuel types, operating procedures for heating systems, and requirements for ventilation are explained. Operating and maintaining the heating system properly are important parts of keeping a home energy-efficient. Selecting and sizing the appropriate new system—if one is required—is also valuable knowledge.

A. Existing Heating Systems

When the heat-energy demand in your home has been reduced through retrofitting, the existing heating system will probably be oversized and operating very inefficiently. Short of replacing the system with a smaller unit, much can be done by the homeowner to ensure that the existing system is working as efficiently as possible.

1. Safety

Family and personal safety should be a primary concern in regard to heating-appliance operation and maintenance. To work properly, this appliance needs an air supply and must be vented to a chimney. The type of chimney will be determined by the type of fuel burned.

The vent-connection pipes to the chimney from furnaces, boilers, stoves or hot-water heaters should be inspected. While looking for rusted or "soft" spots in the pipes, check that all joints are tight and securely fastened. If there are any gaps or holes in the venting system, there is the possibility that harmful by-products of combustion will leak into the home. *Any deteriorated pipes or joints must be replaced immediately.* And make sure that all openings in masonry chimneys—other than those currently in use—are sealed.

Check for obstructions to the air supply. Do not store or place any objects close to a fuel-burning appliance; not only may temperatures be high around it, but combustion air access could be impeded. Ensure, too, that the appliance is not operating in a space that lacks an air inlet.

A shortage of combustion air can be caused by an open fireplace or wood stove. When in use, these consume available air and tend to create a negative pressure in the home. They should have their own combustion air supply to prevent them from creating a draft down the furnace chimney in a house with little air leakage. Such a draft will channel products of combustion into the home. If fireplaces or wood stoves do not have sources of combustion air, a window may have to be opened during their operation.

2. Forced-Air Furnaces

A typical forced-air system is shown in Figure 11-1. Proper and efficient operation depends primarily on regular, yet simple, maintenance.

a) Furnace Maintenance

Before doing any maintenance work on a fuel-burning appliance, *the electrical power switch must be turned off.* This may be an in-line switch located nearby or a separate fuse or circuit breaker located in the service panel. Access panels can then be removed to expose the burner and blower-fan compartments (Figure 11-2).

Yearly maintenance should include vacuuming the furnace cabinet thoroughly. Dust and debris should not be allowed to build up where they can be drawn in with the combustion air required for the burners. The pilot and burner flames should also be inspected annually. The pilot light should burn evenly and be positioned such that

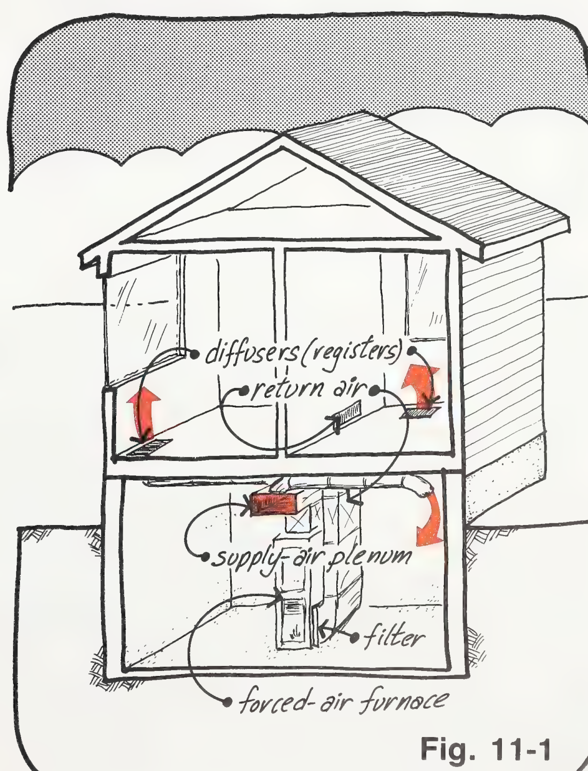


Fig. 11-1

the burners ignite quickly and the safety shut-off thermocouple works as designed (Figure 11-3).

The flame from the burners on gas-fired furnaces must be properly adjusted for best efficiency. If there is an air-control adjustment, it can be set so that a clean, blue flame results. Many furnaces have "shutters", as in Figure 11-4, that can be loosened and rotated to alter the air flow to the burners.

Figure 11-6, and the temperatures at which the switches are set on existing furnaces are often not providing the best efficiency.

The upper-limit pointer determines when the blower fan should start. It should be set at 55°C (130°F). If it is set higher than that, heat is unnecessarily lost up the chimney because the blower fan is not removing it from the heat exchanger. The *lower*-limit pointer determines

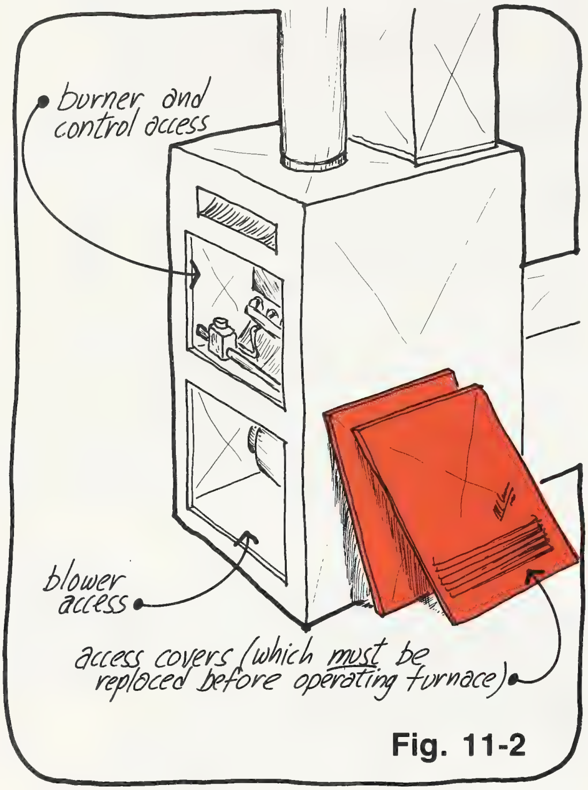


Fig. 11-2

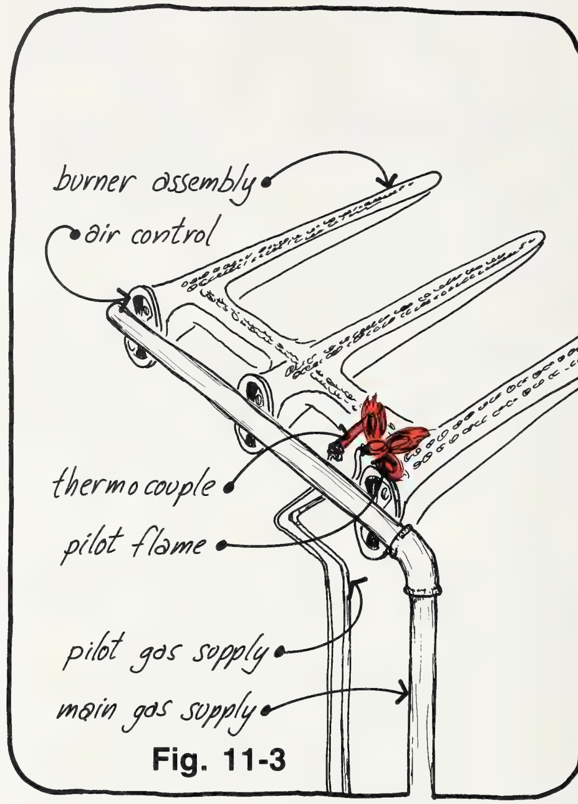


Fig. 11-3

A cross-section of a typical forced-air furnace is shown in Figure 11-5. The heat exchanger is an important part of the assembly: it keeps the products of combustion separate from the heated house air. If you have an older forced-air furnace, it is advisable to test the heat exchanger periodically for any cracks or leaks that may have developed. The easiest test is to burn a small quantity of sulphur in the flame. (This type of test is best carried out by service personnel.) If any odors are present in the house after the test, there probably is a hole in the heat exchanger, which is allowing products of combustion (often odorless) to enter the warm air stream. *Immediate replacement of the furnace is necessary.*

The efficiency with which the heat exchanger extracts heat from the flame source is controlled by limit switches. These vary in appearance from furnace to furnace but usually appear as in

when the blower fan should stop. So when the furnace thermostat indicates the room temperature is high enough, the flame source is extinguished. The blower fan keeps operating, however, until the heat exchanger reaches the temperature of the lower-limit switch. It should be set at 38°C (100°F). If it is set higher, all the potential heat will not be removed from the heat exchanger before the blower fan stops operating.

The most effective, and easiest, part of forced-air furnace maintenance is keeping the filters clean. If the filters become clogged and dirty, air movement slows and efficiency drops because heat is not removed from the heat exchanger as fast as it is produced. To maintain high efficiency, *filters must be cleaned or changed monthly during the heating season.*

The most common types of filters are shown in Figure 11-7. The disposable types, usually of

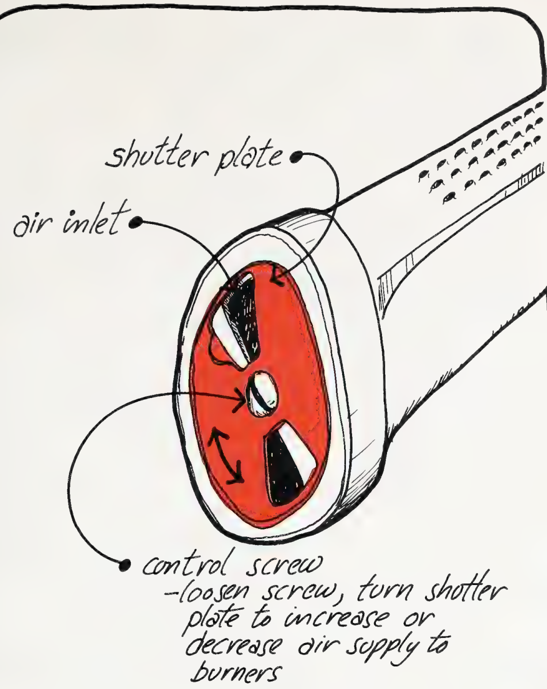


Fig. 11-4

cardboard and fibreglass construction, are held in place with rails or frames set in the cold air return path. Permanent-type filters are removed and cleaned by washing or vacuuming. Other types of filters, such as electronic or charged media, should be maintained as directed by the manufacturer. Whatever type is used, it is important to clean or replace filters on a monthly basis during the heating season.

Twice-yearly maintenance of a forced-air furnace should include motor and blower fan lubrication. Add five or six drops of a non-detergent, electric motor oil to the oil ports at each end of the motor and fan shafts (Figure 11-8). If there are no oiling ports, then the motor and/or blower fan has sealed bearings.

Many newer furnaces have the lower fan directly driven by the motor, the fan being mounted on the motor shaft. However, many older units rely on a belt drive, which should be inspected whenever lubrication is done. Check the belt condition, alignment, and tension. If the fan belt is cracked, frayed, or worn, replace it. Loosen the motor, remove the old belt, install a new one of the proper size, and adjust the tension. Proper tension can be set by adjusting the angle of the motor—there should be 15mm to 20mm (about

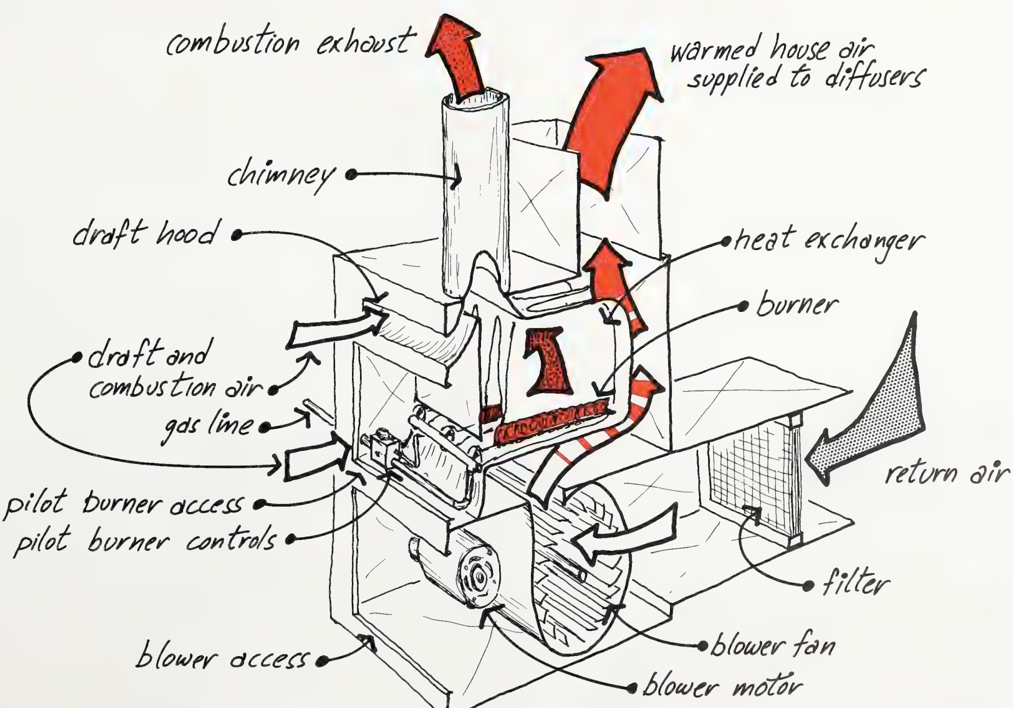


Fig. 11-5

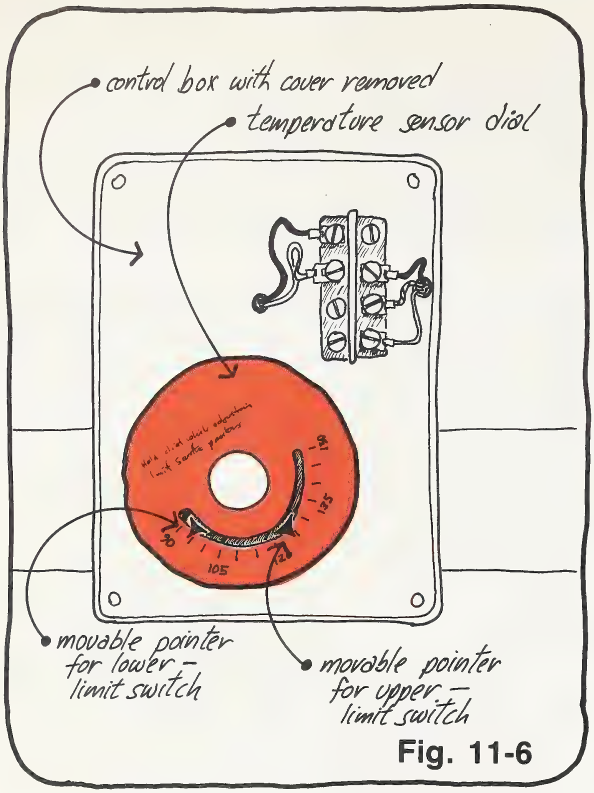


Fig. 11-6

3/4 inch) of slack in the belt midway between the motor and fan pulleys (Figure 11-9). Look along the belt to check that the pulleys are lined up properly. If not, the motor pulley can be loosened and moved one way or the other.

While inspecting and lubricating the motor/blower fan of a forced-air furnace, check the blower fan vanes. Any solid build-up on the vanes will impede efficient operation and air flow. Loosening a few bolts will usually allow the assembly to be exposed enough to scrape and vacuum the blower vanes.

After completing furnace maintenance, make sure that all assemblies removed are remounted (the blower fan unit, for example). Replace all access doors and turn the power back on. *Do not operate the furnace without all access doors in place.*

b) Thermostat Operation

An important aspect of the operation of an efficient heating system is the temperature maintained in the home. Heat loss, you will recall, is dependent on the temperature difference between the interior and the exterior. It therefore stands to reason that the lower you can keep the inside temperature, the less the rate of heat flow through the walls, floors, and ceilings.

A large potential energy saving is possible by turning down the thermostat during the night to 15°C (60°F)—and also during the day when no one is at home—rather than leaving it at 20°C (68°F) all the time.

If you have trouble remembering to adjust the thermostat, automatic setback thermostats are available to ensure that settings are altered each and every day. An override switch on this thermostat enables you to bypass the automatically lowered settings on weekends or when people are home all day.

Automatic setback thermostats operate by using a 24-hour clock or timer that is programmed to raise and lower temperature settings for specified periods. Different units offer various numbers of setback periods—from one per day to eight per day. (Some setback mechanisms can be added to your present thermostat, others replace it.) Most replacement-type units can operate on the existing low-voltage wires to the furnace.

Most automatic setback thermostats can be installed by the homeowner. Those that require additional wiring may pose problems if new wiring is difficult to thread through the wall. When installing a new thermostat, mount it perfectly level on an interior wall and away from any drafts, direct sunlight, or such heat sources as a refrigerator, heat duct, or chimney. The thermostat should be positioned about 1.5m (5') from the floor and away from heavy traffic areas.

c) Furnace Sizing

The ideal situation for home-heating efficiency is to have the proper size of furnace in your home—one that operates 100% of the time on the coldest day of the year.

If an inspection of the existing furnace reveals that it is in good shape and still operating safely, *then it may not be economically feasible to replace the furnace.* Spending a few hundred dollars to gain a bit of efficiency will not pay. You are better off waiting until the existing furnace wears out and has to be replaced.

You may, of course, have a good reason for acquiring a new furnace. An inspection could reveal serious problems—holes in the heat exchanger, burner deterioration, rusting of structural components, or blower failure—that would be economically remedied with a new heating unit. And older furnaces that have been converted from gravity or other fuel systems may have parts or components impossible to replace when they break down. Chimney leaks, condensation from improper operating temperatures, or built-in humidifier overflows may have contributed to the above problems.

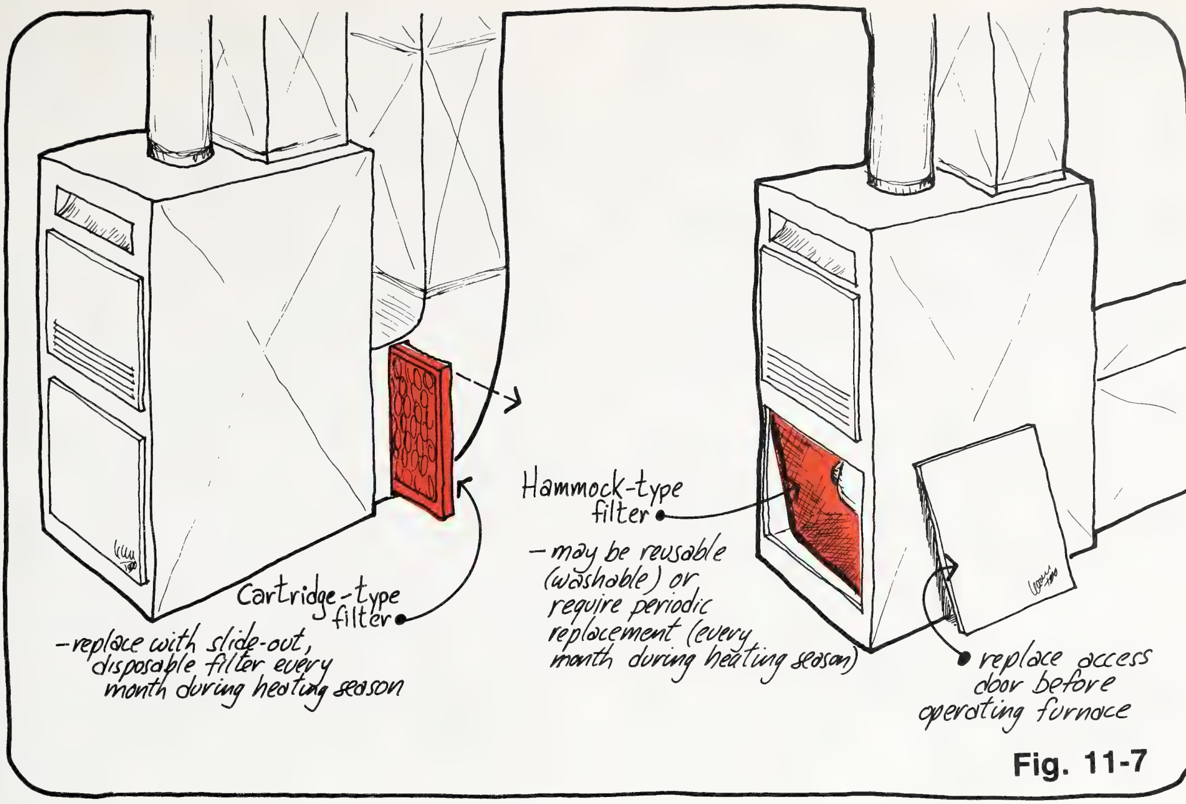


Fig. 11-7

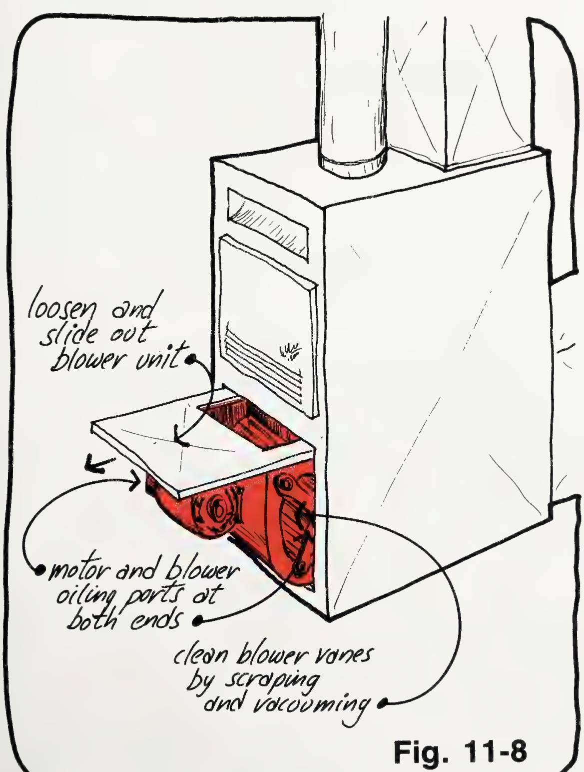


Fig. 11-8

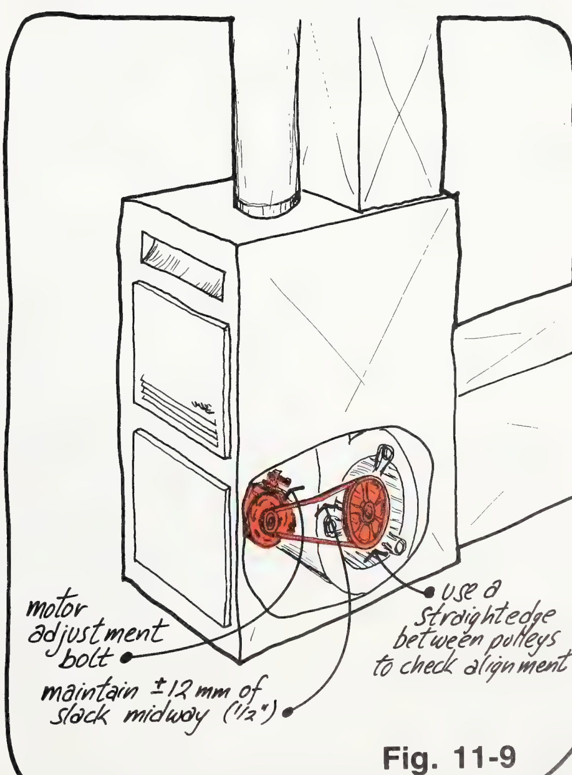


Fig. 11-9

After retrofitting your home, you may find that the existing furnace is too large because the heating requirements have been reduced. On the other hand, plans to add to your home extensively may mean that the existing furnace will be too small.

If you have to replace the furnace, it is very important that the replacement is efficiently sized, because a unit that is too large will operate inefficiently. After the flame ignites, the heat exchanger takes a few moments to warm up before the blower fan starts to move air across it, picking up the heat. When the burner stops, the blower fan continues to run until the heat exchanger is cooled to near room temperature. An efficiently-sized furnace will run almost continuously in cold weather, while a larger furnace will cycle on and off, heating the home in short bursts of operation. However, a furnace is least efficient at start-up and cool-down, so *the fewer the on/off cycles, the better.*

It takes a qualified heating contractor to size a heating unit to a building. Still, make sure the contractor takes into account the following factors when gauging a replacement heating unit for your home:

- the size (volume) of the building
- the actual insulation levels of walls, floors, and ceilings
- the extent of weatherstripping and caulking
- the quality of windows and doors
- the orientation of windows (passive solar gain)
- the number of layers of window glazing.

The result should be a properly-sized unit, one in which the heat output will be only 10% more than is required on the coldest winter day.

d) Types of Forced-Air Furnaces

Forced-air, gas-fired furnaces are available today in three basic categories: conventional; medium-efficiency; and high-efficiency. Your proper requirement depends on a number of factors.

Conventional furnaces in common use are available in a wide range of output sizes—18 kW to 50 kW (60,000 to 175,000 btu/hr). Their main disadvantage is a low seasonal efficiency of 55% to 60% due to pilot flame and chimney losses. "Seasonal efficiency" actually refers to average operation over a whole year. The many cycles of starting, running, and stopping—all under different weather conditions—significantly affect overall furnace efficiency. (Manufacturers'

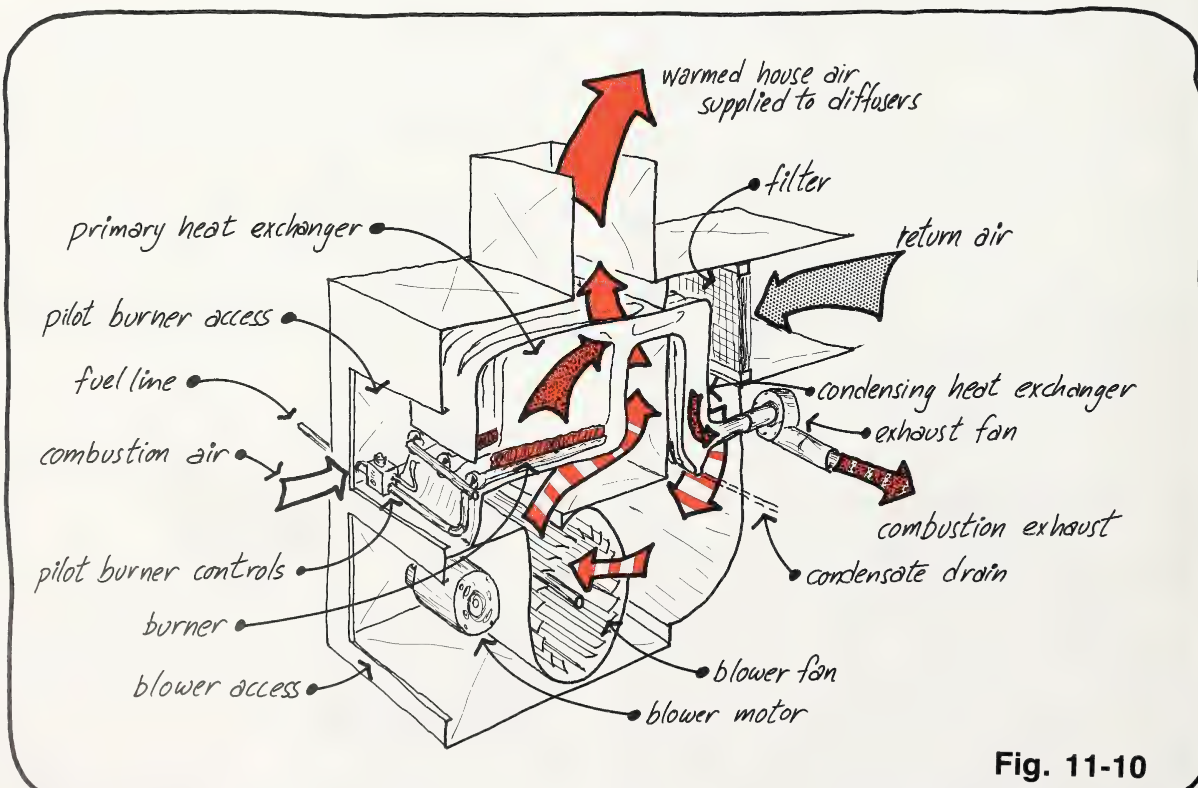


Fig. 11-10

efficiency figures, called "steady state", are higher than seasonal figures because their products are measured under ideal laboratory conditions.) Most conventional furnaces are equipped with two-speed fans, which is an advantage. The lower speed can be used year-round to distribute passive solar heat, plus heat from appliances, lights, and occupants, as well as maintaining humidity and air freshness. The higher fan speed operates only when the burners are ignited to distribute furnace heat. A cross-section of a typical conventional, forced-air, gas-fired furnace is shown in Figure 11-5.

Medium-efficiency furnaces are quite similar in appearance to conventional units. Their main difference is internal. To improve efficiency, the standing pilot flame is replaced by an electronic ignition system, and an automatic flue damper closes the chimney opening when the furnace is not operating. These improvements give these furnaces seasonal-efficiency ratings of 70% to 75%. Because these units are similiar in size to conventional furnaces and are available in sizes of 18 kW to 44 kW (60,000 to 150,000 btu/hr), they can replace existing units with little or no modification to space or ductwork. They are usually supplied with an automatic setback thermostat but do, however, cost about 50% more than a conventional unit—providing, of course, that no substantial changes are required to ductwork, wiring, or furnace position.

High-efficiency furnaces are fundamentally different. They rely on improved combustion techniques and extra heat exchangers to extract more heat from the fuel being burned (Figure 11-10). The extra heat exchangers, usually two more than on a conventional unit, lower the exhaust gas temperature to a point where water vapor condenses and releases a large amount of latent heat. (Because of this, these furnaces are often referred to as "condensing furnaces.") The slightly acidic, condensed water is piped to a floor drain. The cooled exhaust gases are removed with a small blower and plastic piping that vents out the joist space in a home. The main advantage of condensing furnaces is their high seasonal efficiencies of 90% to 95%. They are offered in sizes ranging from 12 kW to 38 kW (40,000 to 130,000 btu/hr). Most units are slightly larger than conventional furnaces and can cost two to three times as much to purchase and install.

Based on efficient fuel use, the high-efficiency furnace appears to be the best choice when you are faced with a replacement situation. However, it is *not* always the solution. If your home has an average or low-heating requirement, the high cost of a condensing furnace is not justifiable. If you have a small house with good insulation levels and a low air-leakage rate, then your home will have a low-heating fuel requirement. If your home is poorly insulated, you will find it cheaper to heat by properly insulating, weatherstripping, and caulking it. For large houses with a high-heating energy requirement, a high-efficiency furnace is the best selection.

If you have a well-insulated home with a few air-leakage heat losses, only a small-sized furnace is required. In fact, your main problem will be finding a furnace *small* enough. Conventional units are often the only ones available with a low-heat output.

B. Types of Fuels

During an extensive retrofit and modification of the heating system, the homeowner may find it convenient to change to another type of fuel. Government incentives to use alternate fuels are another reason for switching.

A number of fuels are commonly used in North America. Table 11-1 lists some of them, along with the quantities required to provide one GJ of useable heat (948,000 BTU). The figures given assume using the fuels in appliances with *typical* efficiencies (for example, gas furnaces at 65% efficiency, electrical resistance heating at 95% efficiency, etc.).

To calculate the lowest cost energy source in your area, obtain local prices for each. Multiply the quantity required to obtain one GJ (gigajoule), and the last column will show you the cheapest alternative available.

Table 11-1 FUEL QUANTITY REQUIRED FOR ONE GIGAJOULE OF USEABLE HEAT

Fuel Type	Quantity	Local Cost	Cost/GJ
Electricity	279,000 watts (279 kwh)	______/kwh	$ ______
Natural Gas	27 m^3 (1185 $ft.^3$)	______/mcf	$ ______
Fuel Oil	34 litres (7.5 gal.)	______/L	$ ______
Propane	53 l (11.6 gal.)	______/L	$ ______
Wood (birch)	97 kg (213 lb.)	______/kg	$ ______
Coal	83 kg (182 lb.)	______/kg	$ ______

The cost of a fuel may not be the only factor you have to consider when making a choice. As indicated below, there are a number of advantages and disadvantages to each fuel. Examine them, keeping in mind that the demand in an energy-efficient home is quite small.

1. Electricity

Since homes require an electrical utility hookup for the operation of lights and appliances, using it as a heating fuel can be very convenient. Although the cost may be high compared to other fuels, the small amount required to heat an

energy-efficient home may still make electricity the best choice. A big advantage to using electricity for space and hot-water heating is the elimination of the need for a chimney—*a large source of air-leakage heat loss.*

2. Natural Gas/Propane

Natural gas is supplied through high-pressure underground lines and requires no storage or handling. Propane needs on-site storage in tanks under high pressure. The gas pressure in either case is lowered by way of a regulator valve where it enters the home. Gas-burning appliances contain safety devices to stop the flow of gas if pilot lights go out or ignition is unsuccessful.

In areas where transmission lines exist, natural gas is often the most convenient and economical fuel to use. However, in locations far from transmission lines, the cost of piping gas to an individual residence can be quite expensive. Propane may be a good alternative if gas is the desired fuel.

4. Fuel Oil

Most fuel-oil installations operate from a storage tank adjacent to the heating unit. There is some inconvenience involved with fuels that must be stored on site—cost of tank, access for delivery, necessity of calling for supply, etc. In many areas, too, service may be difficult to obtain because of limited use of the fuel. Note that oil-burning appliances need regular maintenance in order to operate efficiently.

4. Wood/Coal

The use of solid types of fuel necessitates provision for both access and large storage volume. There must be a ready means of moving fuel into the home and, to a lesser extent, carrying out ashes. Wood- and coal-burning appliances need more attention than gas- or liquid fuel-burning types. *Chimney maintenance is also a critical aspect of operation.*

Using wood or coal does not restrict you to a radiant heat source (such as a simple stove). Forced-air or hot-water heating systems can both be operated with wood- or coal-fired units. But these systems do need filling two or three times a day during the heating season. Wood and coal can be expensive systems for heating if supplies are located far from the point of usage. Further, urban pollution can be a hazard in densely populated areas.

C. Heat-Distribution Systems

There are two basic methods of distributing heat in a home. One uses radiant-heat sources placed throughout the home, while the second uses

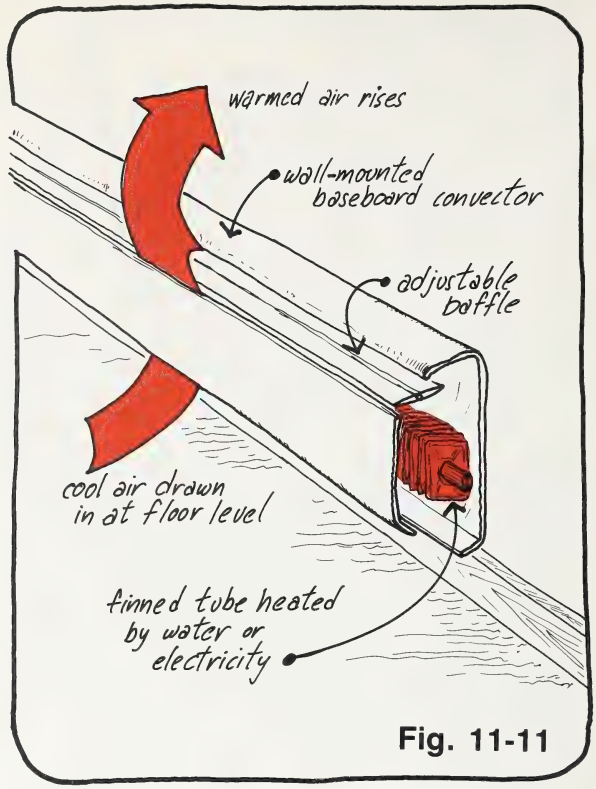


Fig. 11-11

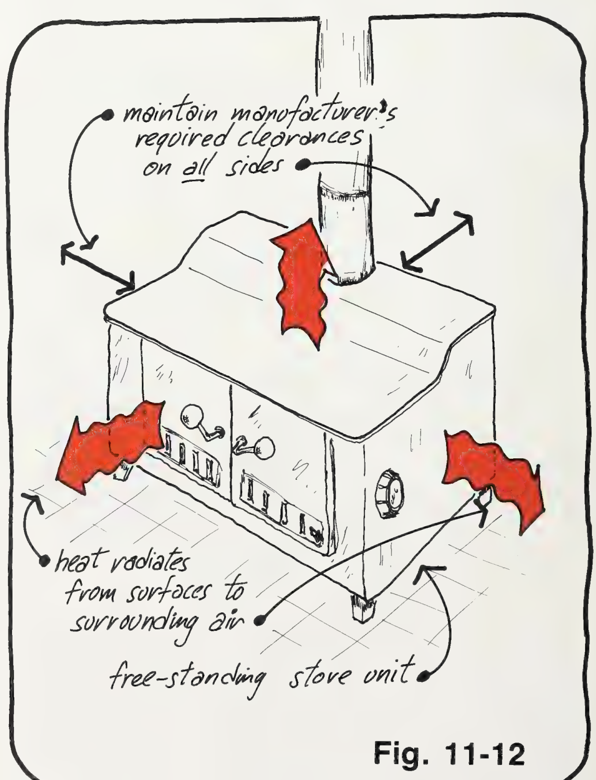


Fig. 11-12

forced-air to distribute heat from one central source. Different fuels and appliances can be used to provide the heat.

1. Radiant-Heating Systems

This type of heating implies a heat source located in a space that radiates heat to the air around it. The action of warmed air rising and cool air falling works to circulate the heat throughout the space. The radiant-heat source may be individual room units (Figure 11-11) employing electricity or hot water. Either type has, or can be fitted with, individual thermostats for temperature control. Hot-water systems rely on a single boiler, which can be fired with *any* type of fuel.

Other types of radiant-heat sources include individual space heaters as, for instance, wood or coal stoves (Figure 11-12). Note that you must be careful to observe the manufacturer's recommended clearances from combustible surfaces when installing these types of units. In addition, to heat an entire home adequately, the design of the plan must be very open or else heat will not distribute evenly to all the spaces. Open grilles can be used to promote hot-air circulation (Figure 11-13).

Another radiant-heat source, although not a very efficient one, is a fireplace. Its poor efficiency can be improved by using a unit that provides control over combustion—glass doors, fresh-air intakes with dampers, recirculating features, etc. (as shown in Figure 11-14). However, *fireplace opening doors and dampers must be tightly fitting to limit air-leakage heat losses when the unit is not in use.*

Radiant floor- or ceiling-heating systems (Figure 11-15) are other options, and they use either heated water or electrical-resistance elements. These systems are difficult to design properly and can create problems if breakages occur but, if installed correctly, do provide a clean, even, hidden source of heating.

2. Forced-Air Heating Systems

A typical forced-air system is illustrated in Figure 11-16. The furnace can be fired with any type of fuel, including electricity, and, in most cases, operates as shown in Figure 11-5. By designing the return-air ducting to draw air from near the ceiling level (Figure 11-16), passively heated air and heat from internal sources that stratify near the top of the heated space are drawn down into the system and distributed throughout the home.

Leaving the fan running constantly *at a low speed* aids the uniformity of heat distribution from passive or internal sources. The fan runs at a higher speed only during actual furnace operation.

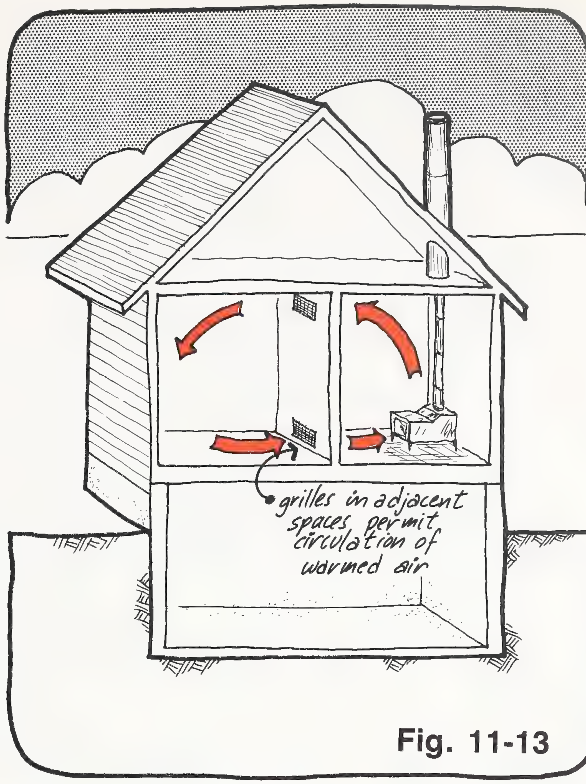


Fig. 11-13

D. Combustion Air

Fuel-burning appliances need air for combustion as well as proper chimney operation. *Since energy-efficient homes will be well-sealed, a separate inlet for combustion air is essential.* In fact, it will probably be a local building-code requirement. Although improvements made to fuel-burning appliances include electronic ignition, chimney dampers, and condensing exhaust heat exchangers, air is still required during flame operation. Fresh air for the occupants is also necessary in well-sealed houses.

Isolating fuel-burning appliances in a room with its own air supply (Figure 11-17) is one way of making sure heated air from the home is not used for combustion. Two inlets into such a space will ensure that there is adequate combustion air, as well as a supply of fresh air to the building.

E. Ventilating the Energy-Efficient House

Fresh air for the occupants of a home is an important consideration in operation. Although the object of a retrofit house is to make it as air-tight as possible, *the entire volume should be changed every three or four hours.* This will prevent a build-up of humidity, odors, and pollutants that occur in a totally sealed space.

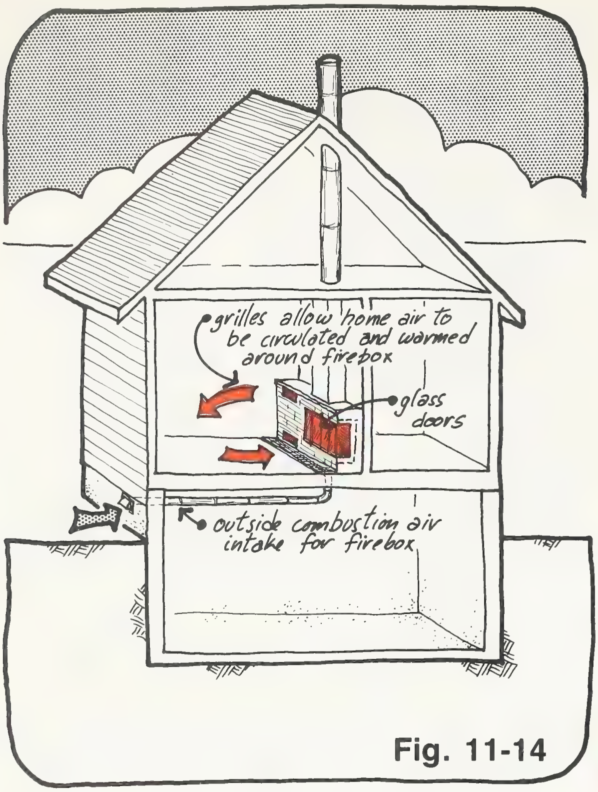


Fig. 11-14

1. Mechanical Ventilation

Mechanical fans can be installed to provide a controlled air-change rate. Humidity levels are the best indicators of a low ventilation rate. As the relative humidity rises, condensation will occur on such cool surfaces as window glazing. If the mechanical ventilation system is controlled by a humidistat, then a comfortable level of humidity can be set, above which the exhaust fan will automatically remove air (replacing humid air with dry, outside air). Override-type switches should be installed in bathrooms and laundry areas to provide short-term, high-velocity, air-exchange rates.

The separate kitchen, bath, and utility area fans that exhaust through the ceilings of standard homes create many hard-to-seal breaks in the air-vapor barrier. When retrofitting a home, the ducts should be placed in interior partition walls (Figure 11-18) and joined in a main exhaust duct that exits out the joist space. This means that only one exhaust vent is required, and one large fan will provide enough ventilation for the whole house. A similar intake vent (spaced at least 1800mm—or 6'—from the exhaust vent) and fan will feed fresh air into the home, replacing the exhausted volume.

2. Air-to-Air Heat Exchanger

Although mechanical ventilation may be required to keep the air in a home fresh and dry, a large amount of heat is lost when air is exhausted. By installing an air-to-air heat exchanger in the exhaust/intake lines of a ventilation system, much of the heat can be recaptured.

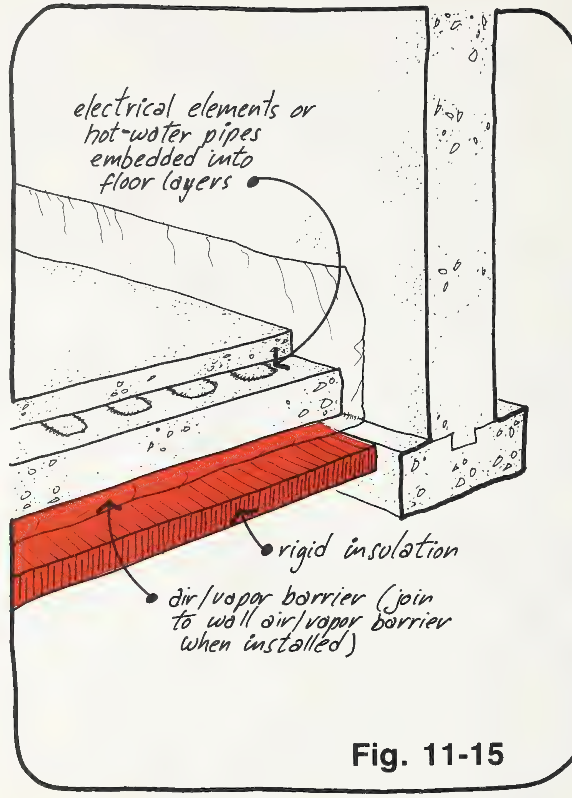


Fig. 11-15

A simple schematic of air-to-air heat exchanger operation is shown in Figure 11-19. One fan is used to draw warm, humid, stale air from the home and pass it through the exchanger, where it gives up most of its heat before being exhausted. Another fan draws in cool, dry, fresh air to replace the air exhausted. This fresh air picks up most of the heat from the exhausting air in the exchanger. Air-to-air heat exchangers are made of many air channels. The exhausting air travels in one direction, and the incoming air travels in the other direction. As the air flows pass each other, the warmer stream transfers heat by conduction to the colder, incoming streams on either side.

Logical areas to locate exhaust grilles (Figure 11-20) are bathrooms, laundry room and kitchen. Clothes dryers and kitchen range hoods should *not* be vented directly into an air-to-air heat exchanger. Lint and grease could quickly plug up the small air channels.

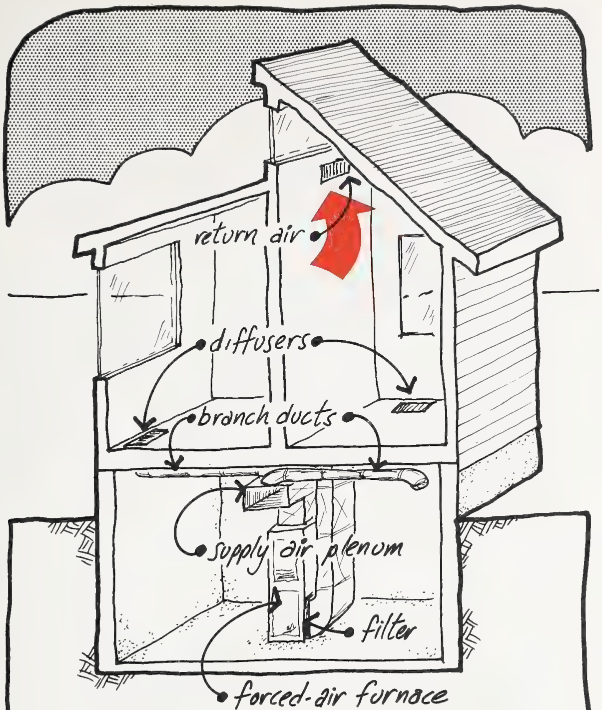


Fig. 11-16

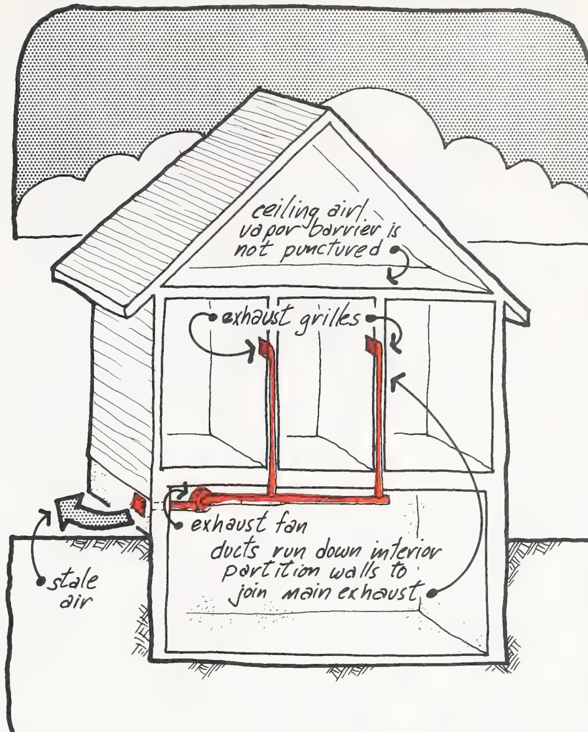


Fig. 11-18

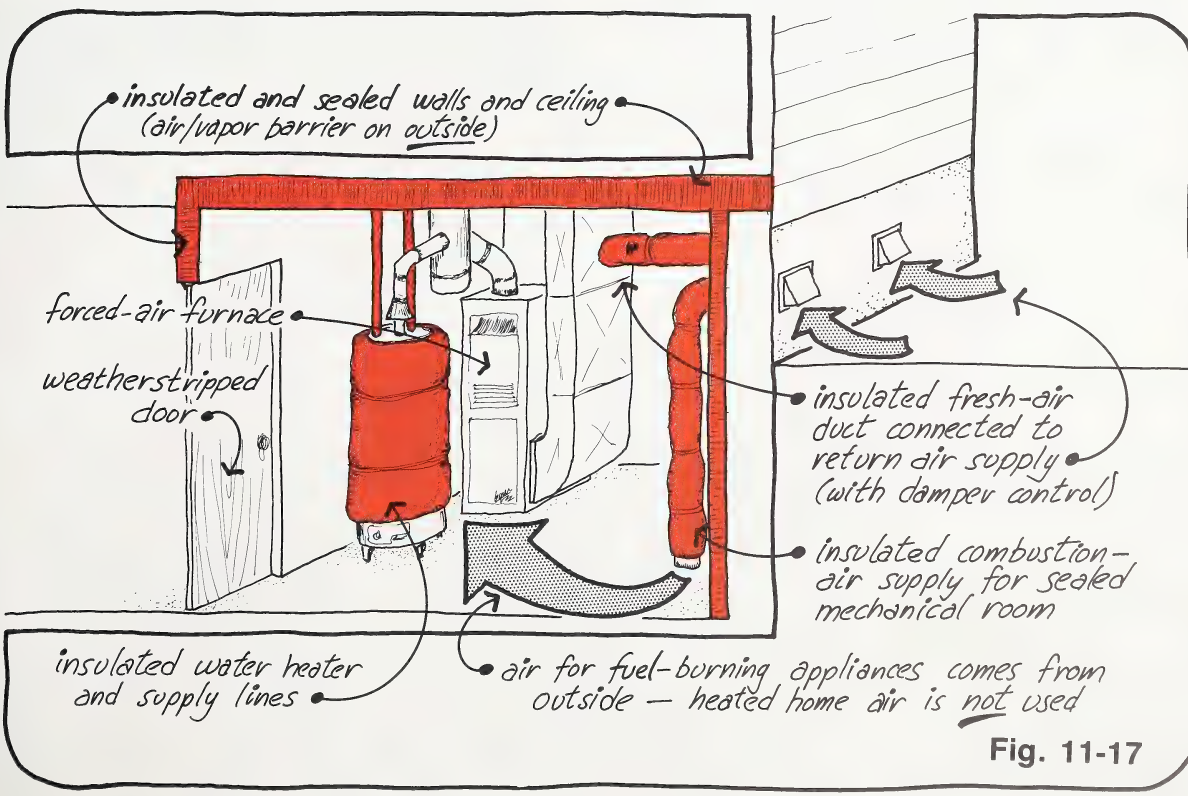


Fig. 11-17

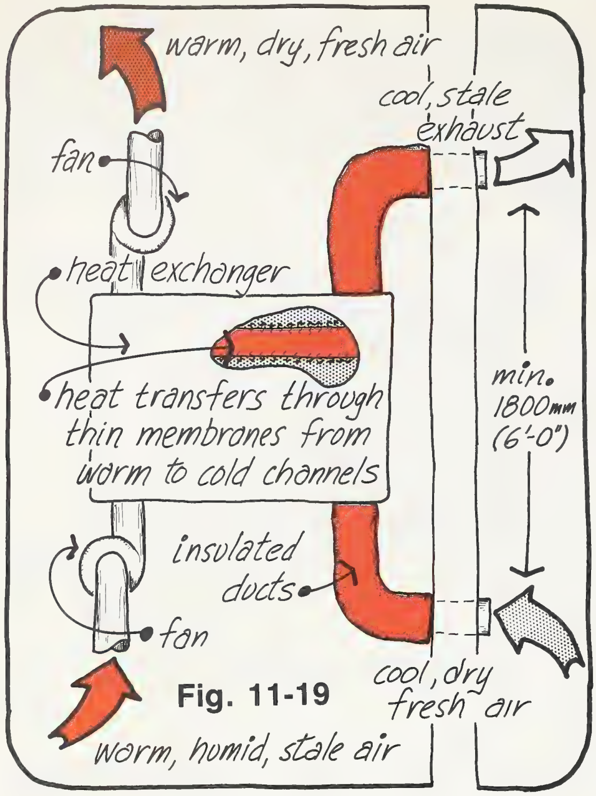


Fig. 11-19

F. Solar Energy

An enormous amount of solar power falls on the earth each day in the form of radiant energy. Any surface exposed to sunlight will increase in temperature as it absorbs radiant solar energy. The basic object of any home solar-energy system is to trap solar radiation and convert it to heat energy. This energy can then be used to supplement conventional home-heating fuels.

Solar energy can be utilized in the typical home by one of two methods—capturing it via an active or a passive system. Active solar-energy systems rely on collectors, fans, or pumps and a storage system. Energy is needed to run those fans and pumps, hence the term "active." The many complex parts and controls needed to operate this type of system make it very expensive to install and maintain, especially in retrofit situations. In cool climate areas of North America, active systems for residential heating rarely gather enough energy to justify their high cost.

Passive solar-energy systems, as illustrated in Figure 11-21, simply rely on parts of the building design and construction for solar heating. The two basic elements of passive systems are south-facing windows and thermal mass. The

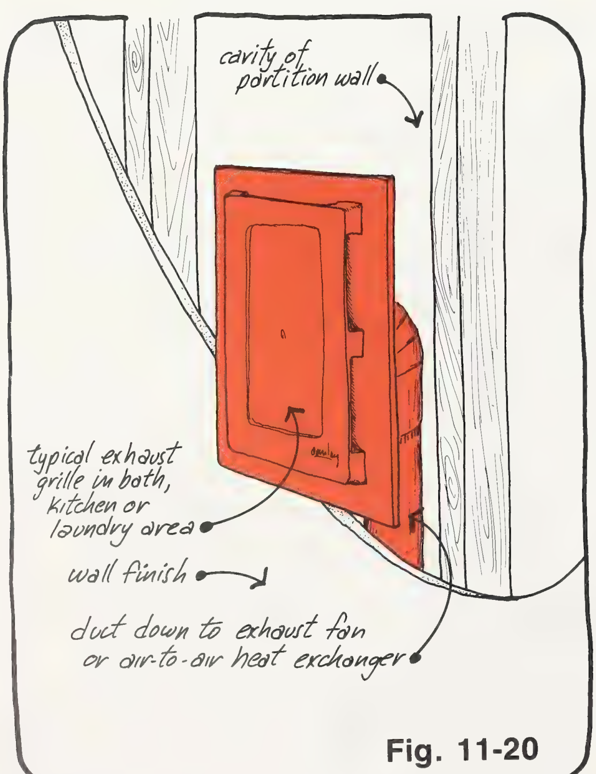


Fig. 11-20

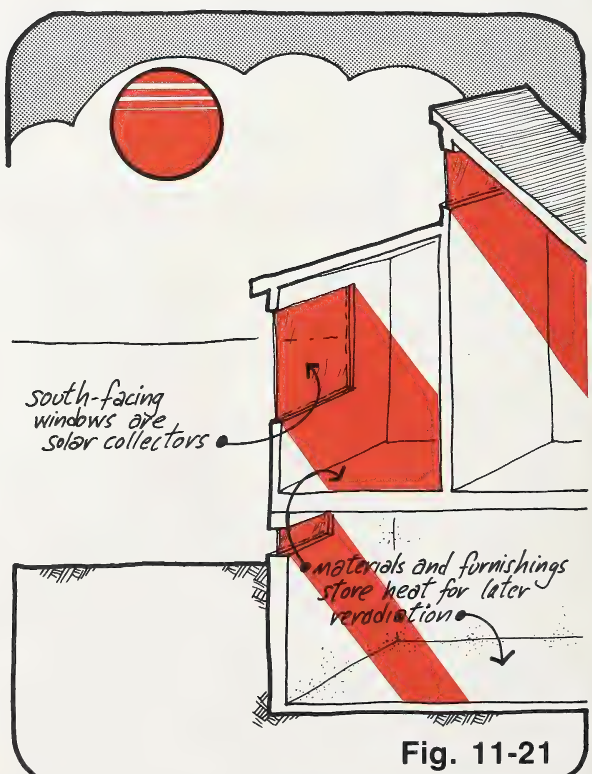


Fig. 11-21

glass allows solar energy to penetrate the space, the mass absorbs the energy, and heat is radiated back into the space when the sun stops shining. Since the systems are an integral part of the building design, or are incorporated into an extensive retrofit, little cost is involved.

Retrofitting a home will result in a lowered demand for heating energy. Therefore, passively collected solar energy can contribute significantly to that lessened demand. Care must be taken, however, to prevent excess heat loss out of windows at night or the benefits of passive solar-energy collection are soon lost. Further, for most of the spring and summer, the design of a passive solar home must be such as to prevent overheating—letting in too much energy. (Details regarding window insulation and prevention of overheating are outlined in Program Six, Section B, Understanding Passive Solar Energy.)

During renovation, there are a number of ways that an existing home can be altered to include some system of passive solar-energy collection. The simplest is to add more south-facing windows in spaces like the kitchen, family room, dining room or living room. Adding dormers to incorporate clerestory windows that face south is another possibility (Figure 11-22). Any planned additions should be located on the south side, if possible with lots of glazing—a sunspace, greenhouse, or an entry way.

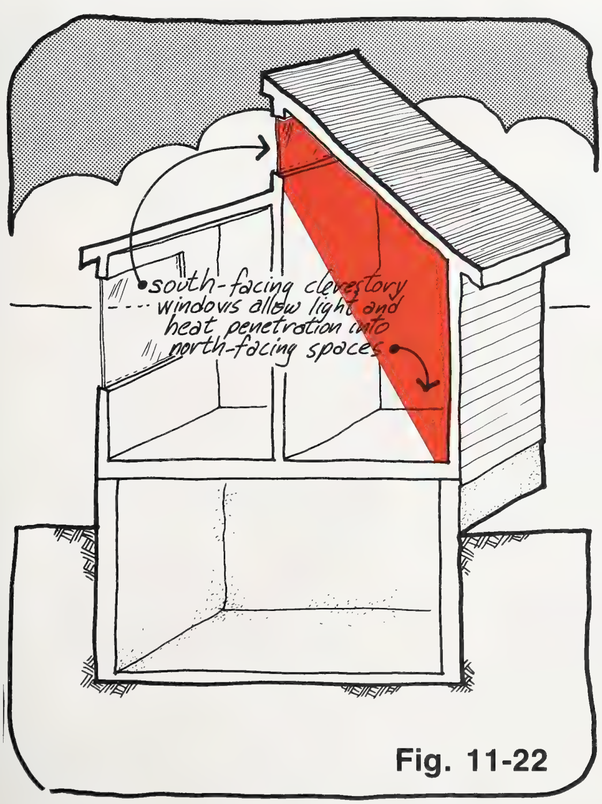


Fig. 11-22

To lower heat losses, site improvements should be considered. Berms and trees provide winter wind protection (Figure 11-23). North-facing windows can be eliminated. Garages or other outbuildings can be so placed as to protect the home from prevailing winds.

Most of the solar energy absorbed as heat energy by the objects in a space simply reradiates back into the space as the air temperature cools. A forced-air heat-distribution system, with the return air intake located near ceiling level (as shown in Figure 11-16), can distribute any passively collected or reradiated heat through the total home. The simplest distribution systems, like radiation and convection, have the least operating problems.

G. Natural Cooling

Higher levels of insulation and a well-sealed air-vapor barrier ensure that a properly retrofitted home will stay cooler in summer, as well as warmer in winter. If you utilize breezes for cooling, air conditioning should *not* be required in most areas of the home. The high insulation levels will lower the heating effect of the sun during the day, and you can take advantage of the site design to promote natural cooling. Design features should include window placement for good cross-ventilation and eaves that shade south-facing windows (Figure 11-24). Minimizing windows on the east and west will lessen the effects of passive solar gain since the sun is always low—even in summer—on those sides of a building.

Plant trees to provide natural shading during the hottest part of the day. Deciduous trees work well in cool climate zones. Their leaves give excellent summer shading but drop off in the fall to allow passive solar benefit in the winter months.

Summary

Energy supplies are dwindling, and energy prices are rising. These are factors over which the homeowner has no control. He or she can, however, control consumption: heating systems should be operated as efficiently as possible.

If new systems are required when renovating, the options available for heating fuels and systems are many and various. A home that has been properly retrofitted to lower consumption will only require a small energy supply, therefore cost may not be the determining factor in choosing a fuel or a heating system. Availability and convenience of use may be the main points to consider.

When dealing with renovation and new systems, the importance of combustion air and fresh air for home occupants must not be overlooked. These aspects should be considered and allowed for when retrofitting.

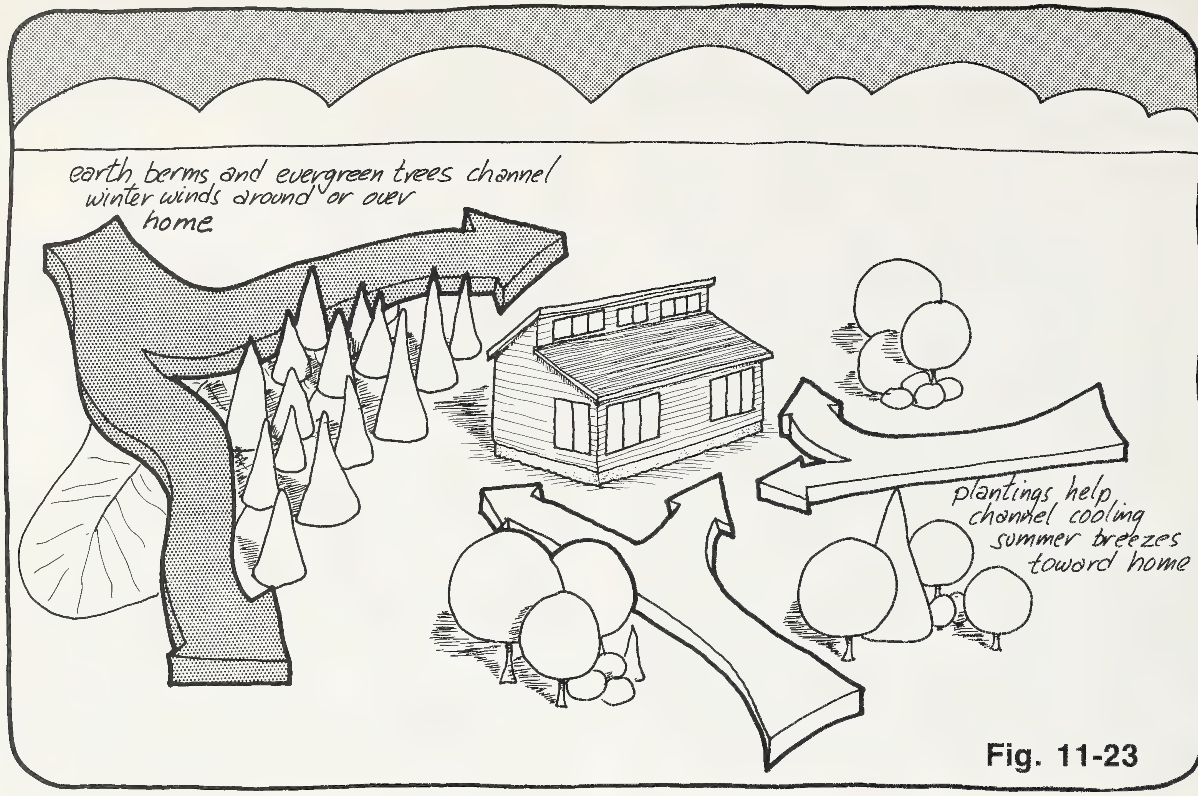


Fig. 11-23

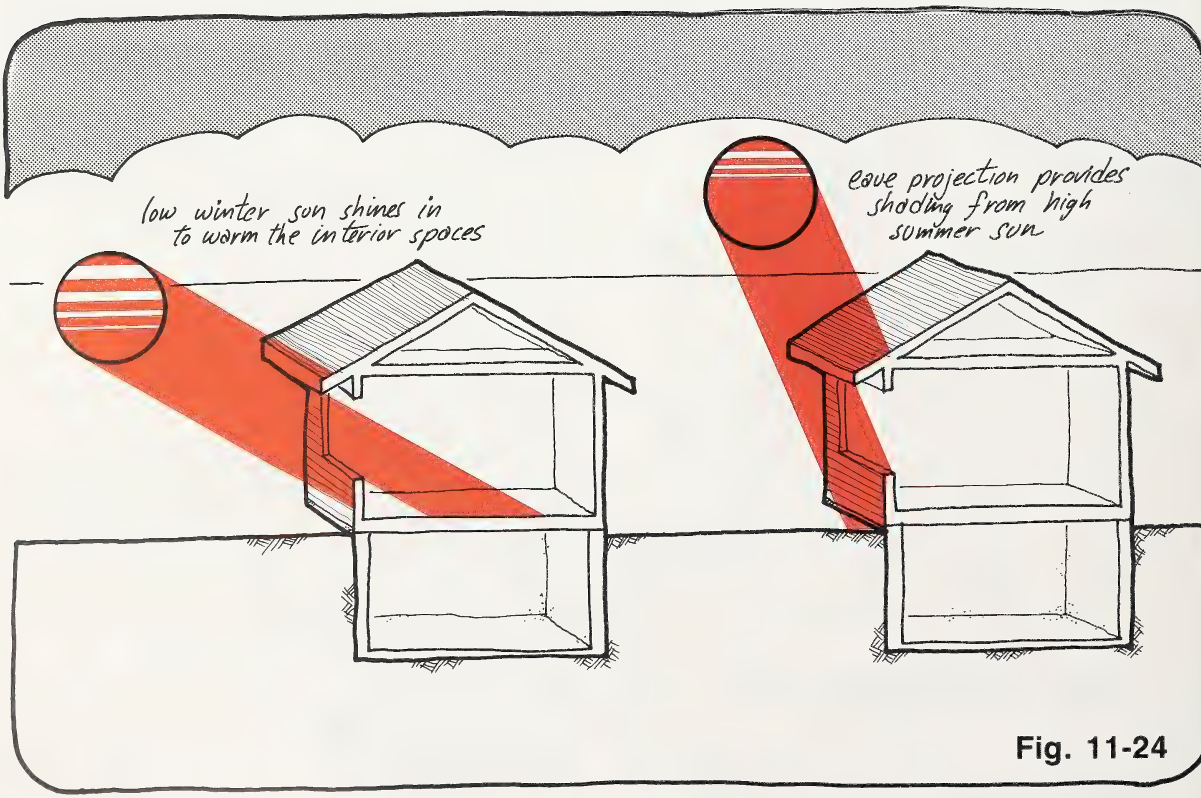


Fig. 11-24

EXISTING HOMES: ENERGY-EFFICIENT LIFESTYLES

OUTLINE

In the past, low energy prices promoted the development of wasteful habits in households. The programs in this series have shown how to lower energy demands with upgraded construction and remodelling techniques. Even more savings are feasible if you develop an energy-efficient lifestyle.

Such changes in lifestyle do not have to be drastic. Simple habits developed in the past—leaving lights or appliances on in unoccupied rooms, for example—can be altered with a little effort, thought, and common sense. This program illustrates typically wasteful habits and indicates new ways to lower home energy demand—and save you dollars.

A. Review of An Energy-Efficient House

Of the total energy a homeowner must purchase each year, two-thirds to three-quarters of it will go toward space heating. The remainder is consumed for lighting, appliance use, and hot-water production (Figure 12-1, left illustration). The foregoing programs in this series concentrated on showing how to lower the space-heating portion of the total energy requirements of a home. The major points emphasized were:

- Minimize air leakage with a well-sealed air-vapor barrier, caulking, and weatherstripping.
- Minimize conduction heat losses with high levels of insulation.
- Provide an adequate, and separate, combustion air supply to fuel-burning appliances to lessen forced air leakage.
- Provide controlled mechanical ventilation to remove excess humidity, pollutants, and odors.
- Recapture heat from exhausting air with an air-to-air heat exchanger.
- Utilize heat gains from such internal sources as appliances, lights, and passive solar energy.
- Maintain and operate all mechanical systems properly to derive their best efficiency.

Whether the preceding practices are applied to a new home or an existing retrofit, the resulting structure will be *more comfortable* and have a much *lower space-heating energy demand*. The portion of energy you have to purchase for space heating will now make up only one-fifth to one-

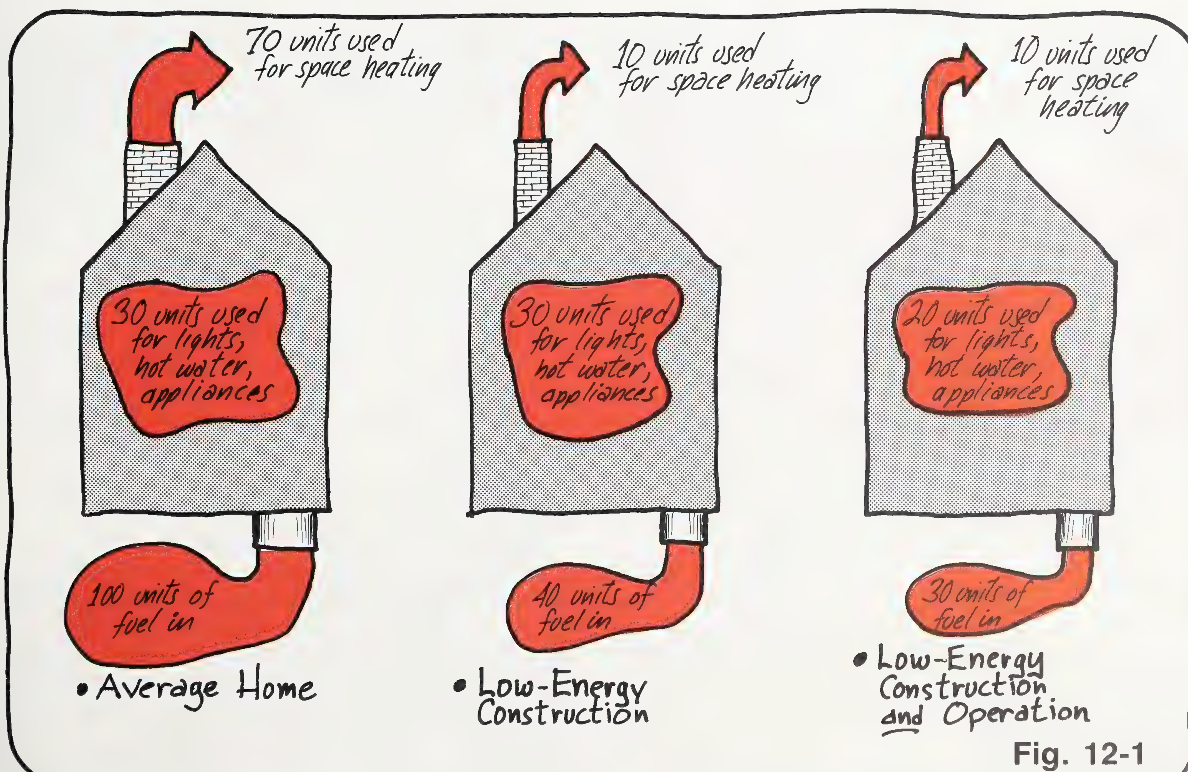


Fig. 12-1

quarter of the total required. Energy for lights, appliances, and water heating will make up the remainder—a proportionately greater percentage (Figure 12-1, centre illustration).

There are many ways in which to lower the energy requirements for lighting, appliances, and hot water heating. Looking at each of these needs separately will reveal just how your total energy demand can be further reduced (Figure 12-1, right illustration). Lighting and appliance energy is supplied by electricity, but hot water can be provided in a number of ways—gas, electricity, or fuel oil.

B. Electrical Energy Use

1. Home Lighting

Numerous simple lighting changes can be made in the home to lower electrical energy demand.

Take note of the lighting in your home and see how many changes can be made as follows:

- Install minimal wattage bulbs in fixtures that do not need to provide a high level of light (in hallways, for example).
- Change 100 watt bulbs to 60 watt or lower in multiple fixtures as the bulbs wear out.

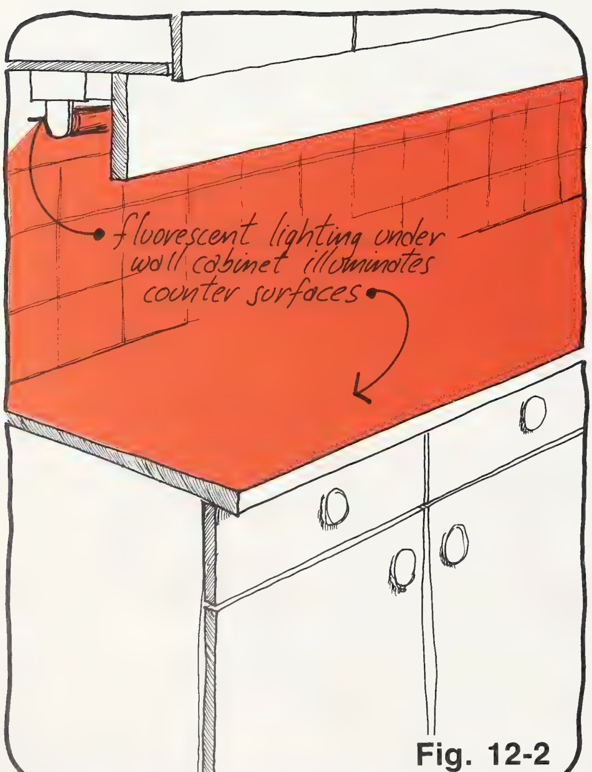


Fig. 12-2

- Provide task lighting (Figure 12-2) in specific areas that require it for reading, sewing, desk or hobby areas—without necessarily illuminating the room in question.
- Change incandescent fixtures to more efficient fluorescent ones in kitchens, work areas, and laundry rooms. (Figure 12-3 shows a fluorescent bulb that can be fitted into an incandescent mounting).
- Arrange work spaces so as to utilize natural light that comes in through existing windows.
- When planning a new home or renovating an existing one, locate windows to provide a good balance of natural light (Figure 12-4).
- Utilize light-colored wall finishes to reflect as much light as possible.
- Install timers or photo-electric controls on exterior lights to eliminate excessive use.
- Install dimmer switches in areas where you want both high- and low-lighting levels.

These energy-saving hints can be utilized when you are designing or renovating any portion of your home lighting. And remember, the simplest and most effective way to save energy dollars is to switch off lights when they are not required.

2. Home Appliance Use

Such appliances as refrigerators, freezers, kitchen stoves, clothes washers and dryers consume a large portion of the electricity you buy. Thus, when purchasing new major appliances, examine their ENERGUIDE labels to find out which products use how much electricity. These labels, the result of a federal government energy-awareness program, state, in kilowatt hours per month, the amount of electrical energy an appliance will consume in normal usage. Thus you can compare energy consumption totals when vetting similar models of appliance. When calculated over the life of an average appliance (10 to 15 years), seemingly small differences in consumption add up to a lot of saved dollars.

In many instances, existing appliances can be used much more efficiently. Clothes washers and dryers, and dishwashers should always be operated with full loads. And washing certain types of clothing in cooler water will conserve hot water. (Smaller loads can be processed only if the water level can be adjusted for this purpose.) A tremendous amount of electrical energy can be saved by air drying clothes on outdoor lines and also by air drying dishes by opening a dishwasher after the wash cycle has been completed.

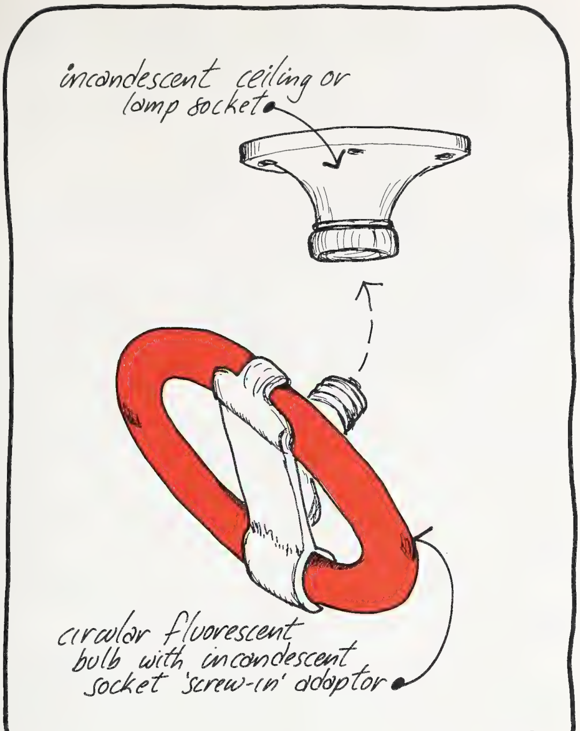


Fig. 12-3

C. Hot Water Heating

Although hot-water heaters have no moving parts, they will wear out over a period of time, usually within 15 to 20 years. But you can do much to improve both their efficiency and life expectancy. Regular maintenance is the key to making a heater last longer, and increased efficiency will result from the following practices.

1. Hot-Water Heat Maintenance

Begin with a quick safety check. In the case of fuel-burning heaters, make sure chimney connections are secure and that the pipes are not corroded. *With every type of heater,* nothing should be on or stored against it. And keep the immediate area around the heater clear of objects of any kind.

Basic maintenance consists of periodic draining to keep sediment from building up. Every month or two, 8 to 10 litres (2 gallons) of water should be drained from the outlet at the base of the tank (Figure 12-5). Drain until the water runs clear, which indicates that all sediment has been removed.

Once a year, the entire volume of the tank should be flushed out to remove rust, scale, and sediment. This build-up lowers the tank's heat-

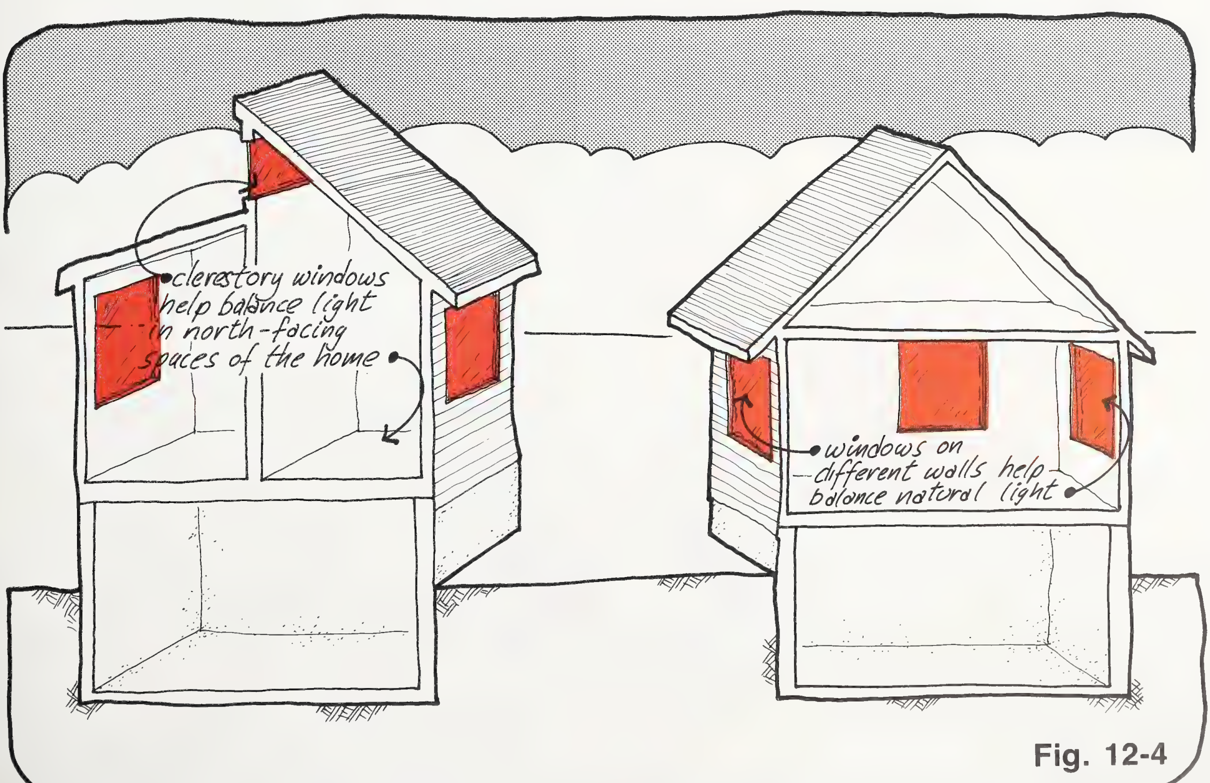


Fig. 12-4

exchange efficiency and contributes to corrosion of the interior. The degree of deposit will depend on the mineral content of your water supply. *Before draining any tank, the power supply must be shut off.* For a gas-fired heater, turn the gas control to "off"; for an electric heater, shut the power supply off at the circuit panel. (With a gas-fired unit, this will necessitate relighting the pilot as explained further on. Do *not* do this if you are not confident about the ignition process—leave the job to a service person.)

To drain the unit completely, shut off the main water supply to the tank and open a hot-water faucet above the tank (in the kitchen, for example). Open the tank drain and allow all the water to flow out. Often a garden hose can be attached and fed to a nearby floor drain. If your tank has not been drained for a number of years, be careful not to force the drain if it is corroded shut—it can easily break off! If a large amount of deposit comes out of the tank, you may want to repeat this process two or three times.

After drawing off all the water, close the drain securely and shut the faucet that was opened to facilitate the draining. Turn the water supply back on and turn the power back on if the tank is electric. For gas-fired tanks, the pilot light must be ignited. There are instructions on the tank, and the procedure is as follows:

- Make sure the gas control valve (Figure 12-6) has been in the OFF position for at least five minutes.
- Open the access doors and find the pilot burner by following the supply line down from the control valve.
- Place a lighted match or taper at the pilot flame, *then* depress the igniter button, which cannot be depressed unless the gas control valve is in the "pilot" position.
- Hold the igniter button down for 30 seconds after the pilot flame is burning.
- Release the igniter button, check that the pilot stays lighted, then turn the gas control valve to ON.
- Check that the flame is operating properly, then close all access doors.
- If the pilot does not stay on, the igniter button has to be held down for a longer time. Repeated failure to restart indicates a more serious problem, which should be remedied by a service person.

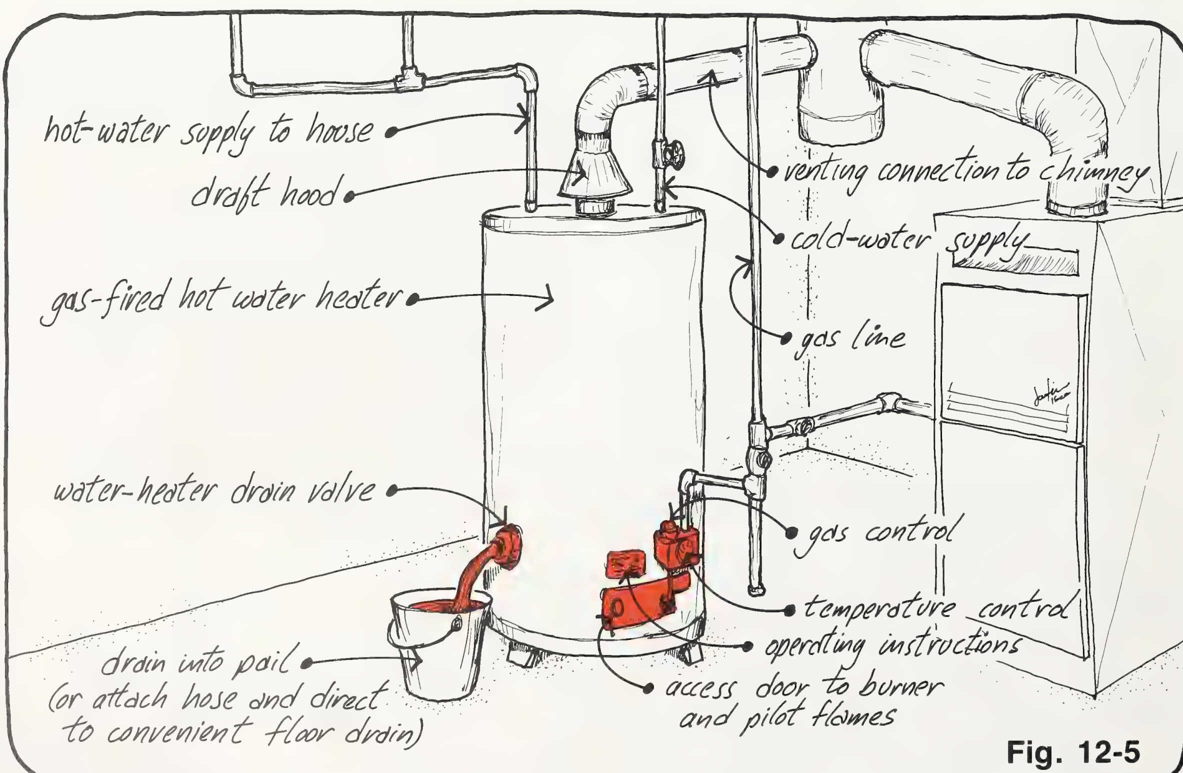


Fig. 12-5

The frequency with which your tank has to be drained will depend on the water supply. If no discoloration appears after two months, lengthen the period between maintenance work.

2. Increasing Water Heater Efficiency

a. Water Temperature

For true efficiency, the water temperature should be no higher than that recommended by the manufacturer—the lower the water temperature in the tank, the less the heat loss through the walls of the tank. If you use an automatic dishwasher, the maximum water temperature should be 60°C (140°F). In all other cases, the temperature should be such that you can just tolerate the touch of the water on your hands (about 45°C to 50°C). This is especially important, from a safety standpoint, if there are small children in the home.

On gas-fired heaters, the water temperature is controlled by a dial (Figure 12-7). Setting the control dial near the middle, usually the "warm" or "normal" position, and checking the temperature with a thermometer enables you to ascertain whether to adjust the temperature up or down.

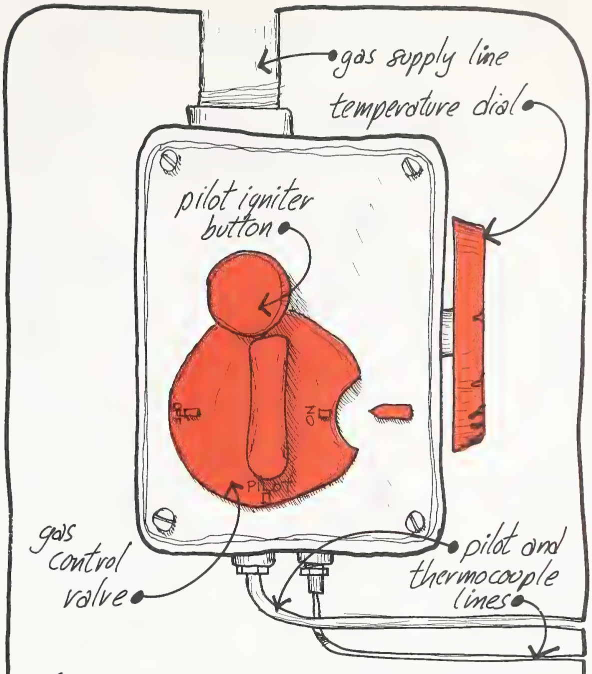
To adjust the temperature on an electric heater, *the power must first be shut off or disconnected.* Two cover plates over the upper and lower element controls have to be removed. The temperature pointers can then be adjusted up or down as needed. Before re-installing the cover plates, be sure that the insulation layer is as undisturbed as you found it. Turn the power to the heater back on *after* the plates are installed.

b. Tank Insulation

To increase the efficiency of older hot-water heaters, an insulation layer can be added to the tank to lower standby heat loss—the loss of heat from the water to the surrounding air. You can purchase a kit or do the work yourself with batt insulation, duct tape, and heavy polyethylene. Figure 12-8 shows an insulation layer applied to a gas-fired water heater. An electric heater can be insulated completely, *but a gas-fired water heater cannot have the top or control area covered.* Covering the top would block the draft hood and affect chimney operation. The control area must be kept clear so that the air supply to the burners is not affected. And, of course, you must always have easy access to the pilot for relighting.

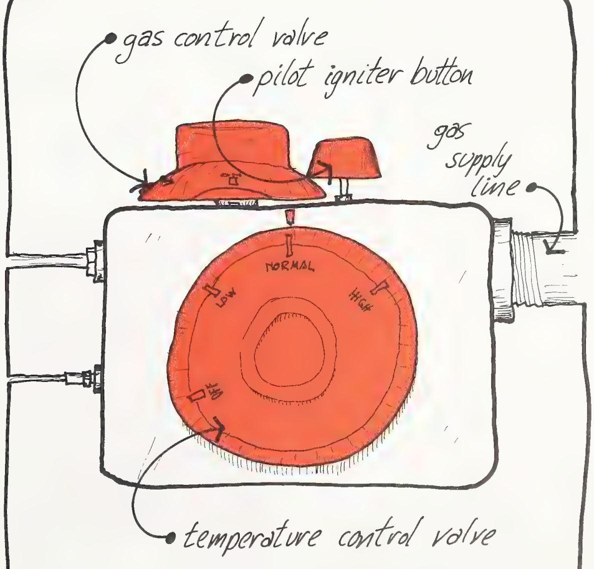
c. Supply Line Insulation

The pipes carrying hot water from the tank are also significant sources of standby heat loss: overnight, and during long periods between use,



Top view of typical gas control valve:

Fig. 12-6



Side view of typical gas control valve:

Fig. 12-7

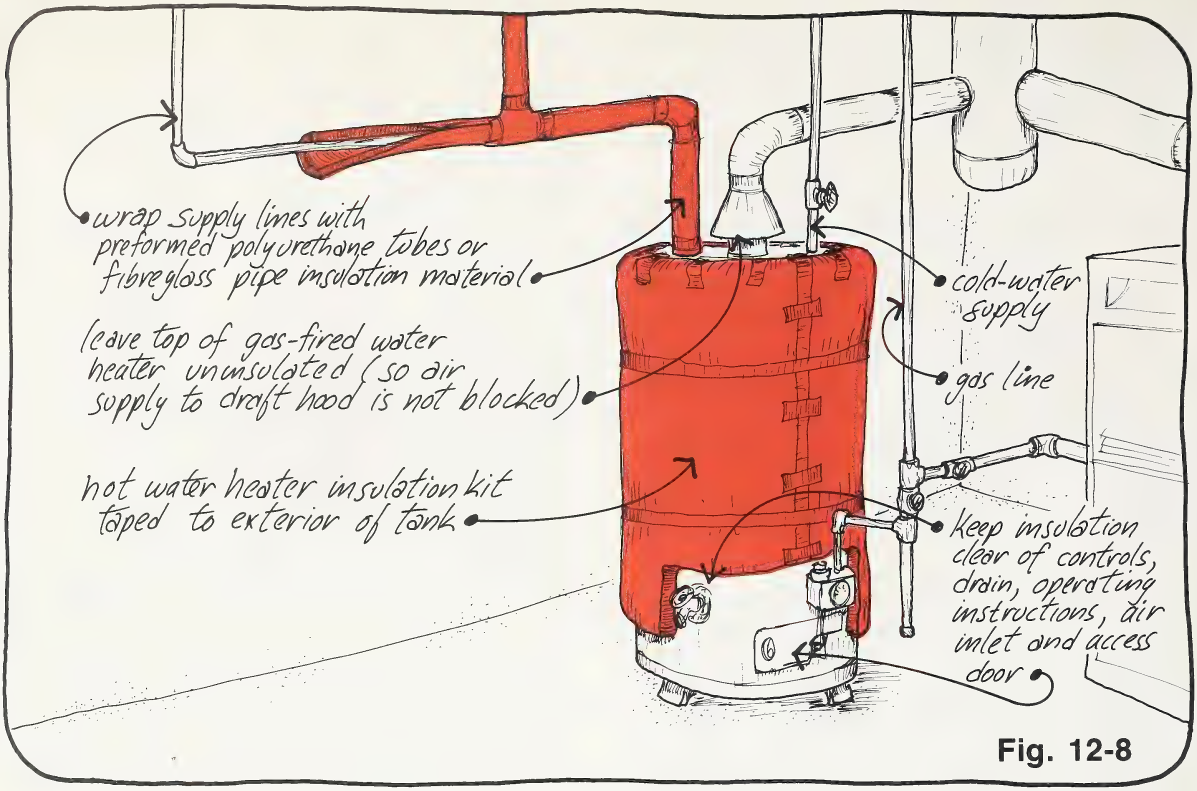


Fig. 12-8

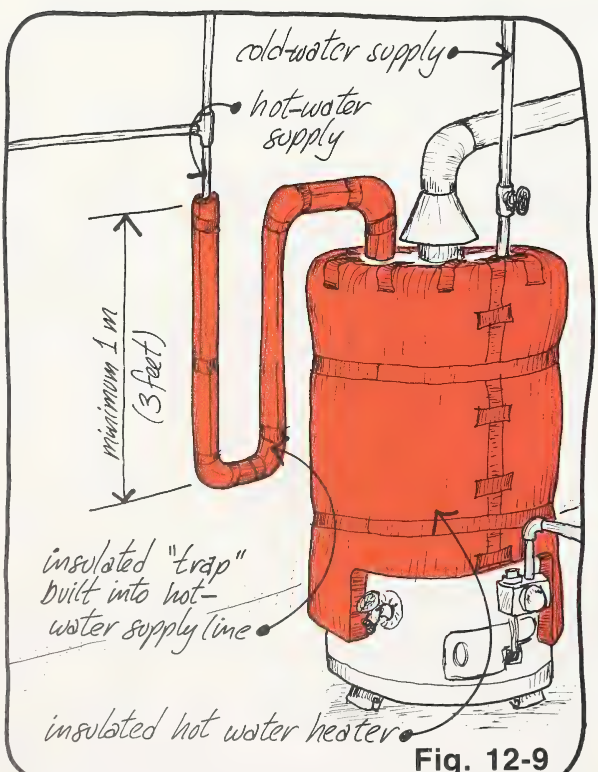


Fig. 12-9

the water cools off, giving up its heat to the air around the lines. Pipe insulation can be purchased and applied. This measure, however, can be quite expensive, especially in a home with many lengths of hot-water line.

An easier, often cheaper, solution is to build an insulated trap into the hot-water supply line. As shown in Figure 12-9, the trap is inserted into the first portion of the pipe. It operates on the principle of convection—hot water rising is stopped at the top of the loop, cool water falling is trapped at the base of the loop. Thus, as the water in the pipes cools during the evening, hot water cannot rise to replace it as it can when no trap is present.

A homeowner possessing simple plumbing skills can easily install a trap in the supply line. Any commercial type of pipe insulation can be used to cover the trap after installation. If the water heater ever needs replacement, consider installing a trap at that time.

d. Water Preheating

Preheating the cold water supplied to the hot-water heater is another way of lowering energy consumption. This preheating can be accomplished with a dark-colored tank so placed as to be solar heated (Figure 12-10) in a

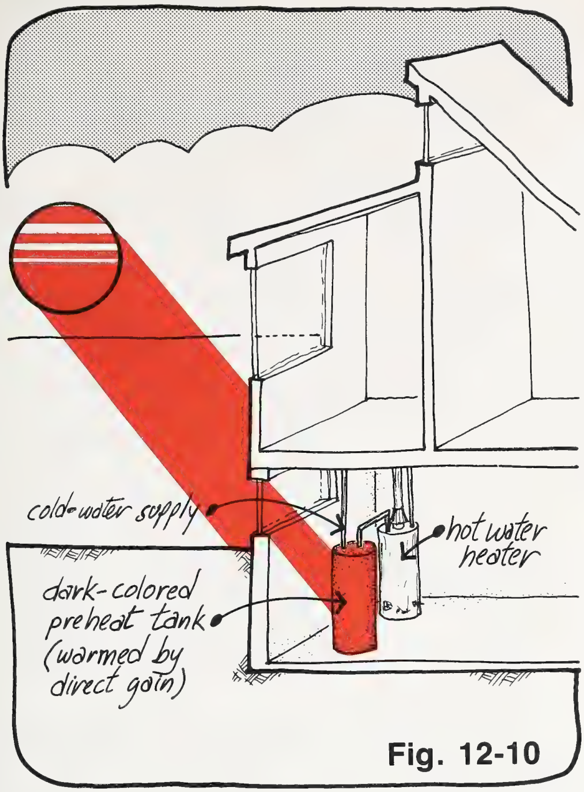


Fig. 12-10

greenhouse, sunspace, or in front of a south-facing window. A tank can also be warmed using water heated in a coil placed in a wood-burning stove. By feeding the cold water supply to the water heater through a coil in a preheating tank, the total temperature the water heater has to raise is lessened, thereby lowering the energy demand.

D. Lifestyle

The lifestyle that an individual or family leads directly affects the amount of energy used. An energy-efficient lifestyle simply means that one does not waste energy—not heating or lighting what is not needed, efficiently using what power must be consumed, etc. A few simple points are:

- Utilize showers instead of baths, since less hot water is consumed.
- Install low-volume showerheads to reduce the amount of hot water used.
- Leave lights and appliances off in unoccupied rooms.
- Turn down the heat in unoccupied spaces.
- Close drapes or window coverings at night to conserve heat energy.
- Make sure drapes on south-facing windows are opened on sunny days to allow passive solar gain.
- Use timers for controlling electrical energy use in situations such as a car block heater. (There's no need to leave it plugged in all night.)

Summary

Low-cost fuels and a seemingly never-ending supply of them has lulled the North American consumer into an energy-wasteful lifestyle. Rising fuel prices have often been viewed as just a part of the general increase in the cost of living. But the tremendous cost of finding and processing new fuel supplies, and the rapid depletion of available conventional sources have combined to raise prices at a much faster rate than inflation.

By reducing requirements for fuel in the home, savings automatically result. Combining an energy-efficient lifestyle with a new or remodelled energy-efficient house will benefit the homeowner now—and as long as the house stands.

BIBLIOGRAPHY

The following is a list of sources you may wish to utilize when you need information on various aspects of low-energy home construction or retrofitting an existing home.

Alberta Energy and Natural Resources. *Low Energy Home Designs.* Edmonton: Energy Conservation Branch, 1983.

This is a book of ideas that lets you do the planning of your own home. It contains a section with 20 different house plans. A second section offers planning, construction, and operating ideas for those who want to design their own home from scratch.

Anderson, Bruce, *The Solar Home Book.* Harrisville, N.H.: Cheshire Books, 1976.

There are many ways of utilizing solar energy, and this book contains detailed instructions on how to do so. It is written in a very straightforward, non-technical manner and is well-illustrated.

Argue, Robert. *The Well-Tempered House.* Toronto: Renewable Energy in Canada, 1980.

A look at how existing low-energy homes are successully operated. The author examines the elements that determine how the basic design of homes function, what materials are used, and how homes are constructed. The emphasis is on conservation and the use of renewable energy sources.

Canada Mortgage and Housing Corporation. *Canadian Wood-Frame House Construction.* Ottawa: CMHC, 1980.

A must for the do-it-yourselfer. This is a manual of how homes are constructed, starting at the foundation, working through the framing and the utilization of mechanical services, and detailing all the finishing steps.

Canada Mortgage and Housing Corporation. *Energy Conservation in New Small Residential Buildings.* Ottawa: CMHC, 1981.

The purpose of this book is to assist homeowners and small construction companies to understand the insulation-level and airtightness requirements of small residences by explaining building practices that meet these requirements.

Canada Mortgage and Housing Corporation. *Energy-Efficient Housing Construction.* Ottawa: CMHC, 1982.

This well-illustrated publication is a basic introduction to the principles and practices of energy-efficient construction. It assumes knowledge of basic construction techniques and concentrates on the features that make a dwelling energy efficient.

Consumer Report. *Money-Saving Guide to Energy in the Home.* Mount Vernon, N.Y.: Consumers Union of the U.S., Inc., 1983.

This publication includes sundry *Consumer Report* studies on home energy use from past issues. It is a collection of product data and operation data regarding many aspects of the home—conservation measures, new equipment, techniques, etc.

Eyre, D., and Jennings, D. *Air-Vapour Barriers.* Saskatoon: Saskatchewan Research Council, 1981.

A very comprehensive guide to the installation of the barrier. It points out some of the changes required in building technology to reflect energy-conservation standards. The techniques illustrated have been developed for a prairie climate.

Flager, Gordon. *The Canadian Wood Heat Book: A Complete Guide and Catalogue.* Ottawa: Deneau & Greenberg Publishers, 1979.

A manual for the homeowner about choosing wood-burning appliances, installation requirements, wood harvesting, and fuel storage.

Housing and Urban Development Association of Canada/Ontario Ministry of Energy. *Builders' Guide to Energy Efficiency in New Houses.* Toronto: HUDAC National Office, 1980.

Builders can use the excellent information provided to improve the quality of their dwellings and provide cost-saving benefits for the owners.

Kadulski, R., and Lyster, T. *Solplan 5—Energy Conserving Homes for Canada.* North Vancouver: The Drawing-Room Graphic Services Ltd., 1981.

An excellent small publication that provides a wealth of building tips as well as a number of plans to choose from. Its climatic design data will be of particular benefit to the home designer.

Langdon, William K. *Movable Insulation.* Emmaus, Pa.: Rodale Press Inc., 1980.

A comprehensive book on effective window-insulating systems. It provides information on those that the average homeowner can build, as well as commercially available systems. Analysis of the various systems includes payback and fuel-saving calculations.

Marshall, Brian, and Argue, Robert. *The Super-Insulated Retrofit Book.* Toronto: Renewable Energy in Canada, 1981.

This is a rare book in that it focusses specifically on renovations for energy conservation. It details and analyses a number of retrofit projects operating successfully throughout Canada. They prove that, just as with new homes, savings more than make up for the costs of retrofitting.

Mazria, Edward. *The Passive Solar Energy Book.* Emmaus, Pa.: Rodale Press Inc., 1979.

This book makes the technical information of passive solar design understandable to anyone—via its many illustrations, photographs, and charts.

Shurcliff, William A. *Air-to-Air Heat Exchangers for Houses.* Andover, Mass.: Brick House Publishing Company, 1981.

The material in this book explores all aspects of the use of heat exchangers to recapture energy from exhaust air.

Shurcliff, William A. *Super Insulated Houses and Double Envelope Houses.* Andover, Mass.: Brick House Publishing Company, 1981.

An examination of the advantages and disadvantages, weaknesses and strengths of the two different approaches to energy-efficient structures.

Shurcliff, William A. *Thermal Shutters and Shades.* Andover, Mass.: Brick House Publishing Company, 1980.

A very comprehensive treatment of the construction techniques, operation, availability, and cost of window-insulation systems.

Walker, Howard V., *ed. Energy Conservation: Design Resource Handbook.* Ottawa: The Royal Architectural Institute of Canada, 1979.

A binder publication containing a summation of relevant energy-conservation material for all aspects of residential and commercial design.

FURTHER SOURCES

Government departments and various other organizations are involved in different aspects of energy conservation and will respond to requests for information. Some will provide advisory services—telephone consultations or individual direct consultations—to help solve problems. The following is a list of some sources of such help.

Federal government

Canada Mortgage and Housing Corporation
Montreal Road
Ottawa, Ontario
K1A 0P7
(613) 748-2000

Has a number of books (see Bibliography), which can be obtained through CMHC regional offices.

Department of Energy, Mines and Resources
Communications Branch
580 Booth Street
Ottawa, Ontario
K1A 0E4
(613) 996-7051

Makes available many research and technical documents, as well as such publications as "Keeping The Heat In", "The Billpayer's Guide to Furnace Servicing", "The Garbage Book."

National Research Council of Canada
Energy Library
Building M-55, Montreal Road
Ottawa, Ontario
K1A 0S2
(613) 993-3861

Technical publications and papers are available through the Energy Library.

Provincial governments

British Columbia Department of Energy, Mines and Petroleum Resources
Conservation and Technology Division
2100, 1177 West Hastings Street
Vancouver, British Columbia
V6E 2L7
(604) 689-1831

Alberta Department of Agriculture
Home and Community Design Branch
Agriculture Building, 7000 - 113 Street
Edmonton, Alberta
T6H 5T6
(403) 427-2184

Alberta Department of Energy and Natural Resources
Energy Conservation Branch
2nd Floor, 10010 - 106 Street
Edmonton, Alberta
T5J 3L8
(403) 427-5200

Alberta Research Council
Solar and Wind Energy Research Program (SWERP)
5th Floor, 4445 Calgary Trail
Edmonton, Alberta
T6H 5R7
(403) 438-1666

Office of Energy Conservation
Saskatchewan Power Corporation
2025 Victoria Avenue
Regina, Saskatchewan
S4P 0S1
(306) 566-3180

National Research Council of Canada
Division of Building Research
Saskatoon, Saskatchewan
S7N 0W9
(306) 665-4200

Manitoba Department of Energy and Mines
Conservation and Renewable Energy Resources
2nd Floor, Colony Square
500 Portage Avenue
Winnipeg, Manitoba
R3C 0E9
(204) 944-2694

Ontario Hydro
700 University Avenue
Toronto, Ontario
M5G 1X6
(416) 592-5111

Ontario Ministry of Energy
Conservation and Renewable Energy
12th Floor, 56 Wellesly Street W.
Toronto, Ontario
M7A 2B7
(416) 965-3051

Ontario Science Centre
770 Don Mills Road
Don Mills, Ontario
M3C 1T3
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Government of New Brunswick
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E3B 5H1
(506) 453-2579

Nova Scotia Department of Mines
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Energy Management Division
1649 Hollis Street
Halifax, Nova Scotia
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(902) 424-3203

Prince Edward Island Department of Energy
and Forestry
P.O. Box 2000
Charlottetown, Prince Edward Island
C1A 7N8
(902) 892-7411

Newfoundland Department of Mines
and Energy
95 Bonaventure Avenue
St. John's, Newfoundland
A1C 5T7
(709) 737-2765

Government of the Northwest Territories
Department of Renewable Resources
Office of Energy Conservation
Yellowknife, Northwest Territories
X1A 2L9
(403) 873-7202

Government of the Yukon Territory
Department of Tourism and Economic
Development
P.O. Box 2703
Whitehorse, Yukon Territory
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(403) 667-5462

Other general sources

BC Hydro
Energy Conservation Division
970 Burrard Street
Vancouver, British Columbia
V6Z 1Y3
(604) 663-3285

Society Promoting Environmental
Conservation
2150 Maple Street
Vancouver, British Columbia
V6J 3T3
(604) 736-7732

Society Environment and Energy Development
Studies (SEEDS)
440, 10169 - 104 Street
Edmonton, Alberta
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(403) 424-0971

University of Regina
Energy Research Unit
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(306) 584-4269

University of Saskatchewan
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(306) 343-2100

The Biomass Energy Institute Inc.
P.O. Box 129, Station C
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R3M 3S7
(204) 284-0472

Manitoba Research Council
#500, 155 Carleton Street
Winnipeg, Manitoba
R3C 3H8
(204) 944-2030

Solar Energy Society of Canada
#608, 870 Cambridge Street
Winnipeg, Manitoba
R3M 3H5
(204) 284-3076

Alternate Energy Resource Centre
Sheridan College, Box 7500
Brampton, Ontario
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Canadian Wood Energy Institute
16 Lesmill Road
Toronto, Ontario
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(416) 445-6296

Energy Probe
43 Queen's Park Crescent East
Toronto, Ontario
M5S 2C3
(416) 978-7014

Pollution Probe
54 - 53 Queen Street
Ottawa, Ontario
K1P 5C5
(613) 233-0260

Ryerson Energy Centre
50 Gould Street
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(416) 595-5071

Ayer's Cliff Centre for Solar Research
P.O. Box 344, Trevail Road
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(819) 838-4871

Brace Research Institute
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Ste-Anne-dé-Bellevue, Quebéc
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Hydro-Quebéc
75 ouest, boulevard Dorchester
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Conservation Council of New Brunswick
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New Brunswick Electric Power Commission
527 King Street
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Cape Breton Alternative Energy Society
P.O. Box 5300
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Ecology Action Centre
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Nova Scotia Power Corporation
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Institute of Man and Resources
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